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The use of multimedia in Telecare systems to improve the performance of users with different cognitive styles

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Abstract: This thesis is concerned with the investigation of methods of providing support to non-expert users of telecare systems by creating easy-to-use interfaces and assessing the effect of adapting the interface to suit the cognitive style of individual users.

The contributions to knowledge fall into three main areas; firstly the innovations built into a prototype adaptive telecare system, secondly the identification of the sort of tasks and the types of media that best suit different cognitive style groups, and thirdly the proposal of a new dimension of cognitive style that classifies individuals by their perception of visual compared to auditory information.

The first phase of the project is concerned with the design and implementation of a prototype adaptive telecare system that demonstrates existing usability principles. The prototype system enables users to communicate over the Internet using text, audio and video, and to enable access to information stored within the system and on the Internet. The adaptive features include the automatic selection of information based on the knowledge of the user and the automatic selection of a presentation style that is based on the way the user perceives information. The system contains a number of innovations that relate to the application of the technology used to build the system, how information is structured, and the design of the style of interaction.

The second phase of the project is concerned with assessing the effect of designing interfaces using different media that are suitable for individual users based on how they perceive and process information. Cognitive style is found to significantly affect performance in few tasks, but relative differences of performance are observed between the cognitive style groups in the different types of task and in the different media versions of each task. A major contribution to knowledge is the identification of the tasks and the types of media that suit different cognitive style groups, as this will help developers of multimedia systems to design interfaces that will improve the performance of users in each cognitive style group.

The major contribution to the field is the proposal of a new visual-auditory dimension of cognitive style. The assessment of cognitive style using a visual test is found to be significantly different to an assessment using an auditory test. An individual's style can be calculated using an existing cognitive styles analysis test augmented by the new audio test presented in chapter 8. The new visual and auditory classification of cognitive style is found to explain the performance of subjects to a greater degree than the old purely visual classification.

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Preface

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1. Introduction

This research project was concerned with the investigation of methods available to provide support to non-expert users of telecare systems. In this context telecare is the use of multimedia PCs connected via the Internet to provide isolated users with face-to-face communications using text, audio and video. Although the main area of interest is telecare the findings of the present research can be applied to multimedia systems in general.

The first main challenge of the project was to investigate methods of providing support to users and to design and implement a prototype using existing usability principles. The original aspect of this part of the project was the implementation of these principles within a new problem domain (i.e. using multimedia within the telecare domain). The second main challenge was to derive recommendations for designing interfaces that would be suitable for individual users based on how they perceive and process information.

The thesis is structured in a manner that reflects the different stages involved in the research project. Chapter one presents the findings of the investigation into the background issues of the areas of interest of the project. Chapter two describes the development of the prototype telecare system that demonstrates an easy-to-use interface. Chapter three discusses the development of the adaptable features of the prototype that can be configured by the user and the adaptive features that are automatically changed by the system to suit the needs of individual users. The adaptive features include the automatic selection of information based on the knowledge of the user and the automatic selection of a presentation style that is based on the way the user perceives information (cognitive style). Chapters four to eight present the results of the investigation into the effects of automatically adapting the interface to suit users' cognitive style. This part of the investigation consisted of a series of experiments that assessed how users possessing different cognitive styles perform when information is presented using different combinations of multimedia. The design of the experiments carried out and the implications of the results are discussed. The conclusions of the research are the recommendations of how to improve the performance of users of multimedia computer systems by automatically selecting and presenting the media and type of tasks that are suited to their cognitive style. Also the thesis proposes a new definition of cognitive style based on the individual's ability to process visual and audio information.

This chapter describes the problem area, and ways of solving it by defining the current state of knowledge in the areas of interest. Such areas of interest include the scope of telecare, how information can be presented effectively using multimedia, how computer systems can automatically adapt aspects of the interface to suit the cognitive style of individual users, and the effect that cognitive style has on user performance.

1.1 The problem area

The problem this thesis attempts to solve is how can the interfaces of telecare systems be designed to improve the users' access to the facilities of the system. In order to explore the background issues to the project a number of questions have to be answered including:
What is telecare?
What features make interfaces easy-to-use?
How can information be presented effectively using multimedia?
How can computer systems automatically adapt aspects of the interface to suit the way individuals perceive information?

The project was conducted in two main phases. In the first phase a prototype was developed that demonstrated existing usability and adaptive principles. Adapting the interface to suit users' cognitive style was identified as an area that required further investigation. Therefore in the second phase a series of experiments were conducted that investigated the effect of adapting the system to suit users' cognitive style. This requires an additional question to be answered as part of the investigation into the background issues:
What effect has cognitive style on the performance of users?

The following sub-sections investigate each of the above questions, examining the current state of knowledge about each area and indicating the features that influenced the development of the prototype. The knowledge gained by building the prototype and by performing the experiments in this project are presented in later chapters.

1.1.1 Telecare

Telecare is the use of telecommunication technology (including phone lines, video phones, Internet access) for the delivery of primary care to the elderly, house-bound, disabled or otherwise disadvantaged, in their own homes (Doughty et al., 1996; Garner et al., 1995; Webster et al., 1995; Ballabio & Cullen, 1997; Barnes et al., 1998). There are a number of different types of user of telecare systems, including patients, their care workers and health professionals. Therefore, there is a need for some level of system intelligence in order for the system to cater for all types of users (Brownsell, 1999).

There are three main services that telecare systems provide. These include:

- monitoring,
- providing security and
- information (Barnes et al., 1998).

The monitoring service includes the biomedical monitoring of patients' heart rate, blood pressure, body temperature etc. by medical professionals at a remote site. Such activities require specialist equipment to cope with communication and alarms (Williams et al., 1996; Williams et al., 1998; Lee et al., 2000). An ordinary multimedia PC was used for this project to simplify the monitoring functions.

The provision of security service relates to the communications facilities of the system. Users are able to have face-to-face conversations with a range of different types of user including health care professionals, doctors, social care professionals, voluntary agencies, self-support community care groups, family, friends or previously unknown people who share the network.

Remote consultation between doctors and patients using videophones (*Telemedicine*) enables the visual examination of surface tissue, such as rashes, bumps and swellings and other activities that require the active participation of the patient and the observation of a trained person, for example measuring blood pressure. It also allows the use of visual testing of cognitive response, memory and reaction time required for the detection of symptoms of dementia, confusion or stroke (Welsh et al., 1993).

The communications network creates a virtual community or *virtual neighbourhood* of users dispersed geographically over many miles who are linked together using the telecare network (Doughty et al., 1996). The increased opportunity for social interaction by users who live alone may help relieve feelings of isolation and depression (Takano et al., 1995) and may motivate users to take a pride in their appearance and not neglect their personal hygiene (Doughty et al., 1996). The sense of security and relief from anxiety that access to professional help and the virtual community provides is expected to improve the quality of life of users, reduce the costs of professional care provision and help facilitate equity of access (Garner, 1995).

The information service provided by telecare relates to the demand of the users for medical and other information. It is expected that in the future the elderly or disadvantaged who are the target users of telecare systems will be better educated and more demanding than previous generations. Many will remain active in mind and limb, demanding not only companionship but also intellectual challenge and stimulation from telecare applications. These individuals will expect to be kept informed about their social and medical condition and may wish to have access to all data generated on them by the system in order to understand any problem and to take appropriate remedial action whether medical or physical (Stoller et al., 1993; Cramp & Carson, 2000; McKeown et al., 2001).

This thesis aims to provide recommendations to improve users' access to the facilities provided by telecare systems. Telecare is intended to provide a service for the elderly, disabled or otherwise disadvantaged and so it is anticipated that they would not be expert computer users. The aim is not to train them to become expert computer users but to present interfaces that enable them to successfully accomplish the tasks they want to perform. As the location of each user is in their own home they would not have easy access to technical help, therefore the prototype was planned to be as simple to use as possible. The challenge was how to develop interfaces that will help them navigate the system in a manner that will achieve their information and communication aims. The majority of the work on the prototype concentrated on devising methods of structuring the information and assisting users to access the information.

1.1.2 Designing easy-to-use interfaces

There are many recommendations of features that can make computer interfaces easy-to-use (Helander, 1988; Nielsen, 1989; Tognazzini, 1990; Mountford & Gaver, 1990; Wagner, 1990; Dix, et al., 1993; Eberts, 1994; Edwards, 1995). The underlying principles can be summarised in *eight golden rules* of interface design (Shneiderman, 1998):

1. *Strive for consistency.* Provide a consistent *look and feel* of the interface, including both the appearance of objects on the screen and the method in which users perform tasks. When the interface looks and behaves consistently it is easier for users to predict the outcomes of certain actions.
2. *Enable frequent users to use shortcuts.* Allow users to quickly return to particular places in the system without forcing them through a long route each time. This may involve allowing users to create their own *bookmarks* to specific places or providing a menu system that enable different routes to the same place.
3. *Offer informative feedback.* Design context-sensitive help information and user instructions that are meaningful and fulfil the users' expectations.
4. *Design dialogs to yield closure.* Indicate to users what their current location within the system is and indicate when individual tasks or sections are completed.
5. *Offer error prevention and simple error handling.* Implement an error trapping and reporting mechanism to ensure that the user is made aware if certain operations have failed and do not allow the system to remain in a non-working state.
6. *Permit easy reversal of actions.* Keep a record of the user's route through the system and provide a *back* button to enable them to retrace their steps and undo certain operations.
7. *Support internal locus of control.* Enable features that make users feel that they are in control and are not being controlled by the system. Allow users to select the functions of the system they want to use and follow their own route through information.
8. *Reduce short-term memory load.* Cut complex tasks into short steps or provide adequate instructions so users can understand the task without having to remember long instructions.

The prototype was designed to provide an interface that incorporated features that make the system easy-to-use implementing the above principles wherever relevant.

1.1.3 The presentation of information to users

An important aspect of telecare is the presentation of information and so an important aspect of this research is determining how information that is contained within multimedia should be structured in a manner that will assist users to access it efficiently.

Dividing the information into small units with links to related units (Hypermedia) allows information to be organised in a non-linear manner that can be easily and rapidly accessed (Conklin, 1987; Nielsen, 1993; Whalley, 1993). Users are able to control their route through the information which increases their involvement in the learning process and may improve their understanding and recall of the information (Marchionini, 1988; Jerke et al., 1990).

While there are great potential benefits in the use of hypermedia, there are also a number of problems. There is evidence that not all users choose the links that best fit their needs and some prefer to be led (Jaynes, 1989; Jonassen & Grabinger, 1990; Jacobs, 1992). In large information spaces it is easy for users to be distracted by irrelevant links and become disorientated (Conklin, 1987; Campagnoni & Erlich, 1989; Hammond, 1993; Hendley et al., 1993; Rossi et al., 2000).

There are a number of established techniques that help users successfully navigate through hypermedia (Conklin, 1987; Marchionini, 1988). These include:

- Provide an organisational structure (such as a hierarchical structure or map) that indicates the contents of the information space.
- Indicate where the item that is currently displayed is within the organisational structure.
- Provide an index of all items within the information space.
- Provide a search query mechanism.
- Enable users to go back to previously viewed items.
- Recommend a route through the information.
- Automatically select the most appropriate item for the user to view.

Methods of automatically selecting the most appropriate item that suit the individual needs of users are explored in the next section.

1.1.4 How systems can be made to adapt to individual users

Telecare systems are designed for non-expert computer users and so require easy-to-use interfaces. Usability principles aid the development of such interfaces, however, the specific types of user that telecare is aimed at may require additional support. One method of providing intelligent support is to automatically change aspects of the interface to suit individual users. The system may select different information to present to different users, automatically determining the optimum way to structure the information, which media to use and what options to present to the user. This section explores methods of adapting interfaces to suit the individual needs of users by investigating the situations where adaptive systems are useful, and the mechanism that enables systems to adapt.

1.1.4.1 Automatically adapting the interface to suit individual users

There is an increasing need for computer interfaces that can adapt to meet the requirements of individual users. In the past computers had limited resources and could not support extensive user interfaces, therefore they often had to be operated by the experts who programmed them. These expert users required a limited interface and had to perform many data preparation tasks in order to optimise the computer's resources. As computers have become more powerful with multimedia and communications abilities the applications that can be run have become progressively more complex while the range of users with differing levels of expertise have become wider (Ambrose, 1991; Benyon & Murray, 1993b; Thomas, 1993; Trumbly et al., 1994). As computer programs have become more complex there is a need to give additional help to ensure that the full functionality of the system is accessible to the user. There is also a need for better interfaces to facilitate the repetitive tasks performed by users at work such as data entry. Improving the performance of the workforce by a small fraction is significant. Different types of user may require different sorts of assistance, and individual users may require different sorts of help as their needs change over time (Benyon et al., 1993a; Benyon et al., 1993b; Hendley et al., 1993; McTear, 1993).

One approach of supporting users is to provide them with intensive training in order to operate complex systems. Users will be forced to adapt their approach and behaviour in a uniform manner that suits the developers of the system. The opposite approach is to build several different versions of the same system, each with interfaces that suit different types of user. Users will be faced with the task of choosing the correct version of the system that suits them. One of the drawbacks of the second approach for system developers is the increased overhead of having to build different versions of the same interface. Drawbacks for the user include increased uncertainty for users who may not have the necessary experience or knowledge to make the correct choice of system interfaces and the extra burden of having to learn a new set of operations if they change versions. An alternative approach would be for the computer system to assess the needs of the user and automatically adapt aspects of the interface to suit them. The whole system would not have to be reproduced as only the aspects of the system that require alternative versions would need to be developed.

1.1.4.2 The adaptive mechanism

When interacting with others we adapt our behaviour to suit what we know, or think we know about the people with whom we are interacting. In the same way, a computer interface can be made to adapt to individual users based on information it holds about them. This section examines the mechanism that enables computer systems to automatically adapt aspects of the interface to suit the characteristics and needs of individual users. The interaction can be based on appropriate characteristics of the user's that are stored in the system.

Adaptive systems dynamically change aspects of the interface in response to information that is gathered about the user by monitoring their actions. The adaptation process that takes place depends on the aspect of the system that is being adapted. Some aspects require constant monitoring such as the selection of information to display as the user's knowledge is constantly changing, while other aspects are static such as the style of presentation that should not be changed after the user's preferred style has been determined. Using information the system "knows" about the user, it can make decisions about what information to display and the most effective way to present it to the individual.

A computer system that provides information can adapt by the interaction of three components:

- the *knowledge domain*,
- the *user model*, and
- the *rules* that govern how the user can interact with the *knowledge domain* (Self, 1988; Bocker et al., 1990; Benyon & Murray, 1993b; Elsom-Cook, 1993; Brusilovsky, 1996; Hohl et al., 1996).

The *knowledge domain* is all the information contained in the system that can be presented to the user. In the case of the prototype telecare system this includes medical dictionaries, articles, tutorials, literature and galleries of images as well as system-specific information including the help files and instructions that are given to the user. This is a relatively static body of information.

The term *user model* has been employed in several senses including both the knowledge about individual users, and the inference mechanism that differentiates the interaction between individuals (Allen, 1990). This project makes the distinction between the data specific to one individual (the *user model*) and the inference mechanism that is applied to all users (the *rules module*). The individual user models contain all the information about the users that is required by the system in order to make the decisions of how best to present information (Kass, 1987; Benyon & Murray, 1993a; Elsom-Cook, 1993; McTear, 1993; McTear, 2000). This information is dynamically updated as the user interacts with the system.

The *rules module* governs the interaction between the user and the system. This is split into two areas; the *user modeller* that determines how information about the user is gathered and maintained, and the *Interface Manager* that makes the decisions of how to design the interface based on the information contained in the user model (Perez, 1995).

Figure 1 demonstrates the interaction between the components that comprise an adaptive system, the *knowledge domain*, the *user model* and the *rules module* (which is represented by the *user modeller* and the *interface manager*).

The *user modeller* monitors user actions which are input through the keyboard, mouse or voice commands. All user actions are compared with what is already known about the user and stored in the user model (e.g. assessing whether their selection of information is consistent with their learning aim). If the action is inconsistent with what is expected the *user modeller* makes an assessment of what the reason is for the difference (which may be that the user is making an incorrect choice and requires help to make correct choices or that the user model has incorrect information about the user's goals). The *user model* is then updated with the new information (which may be newly identified characteristics of the user or a record of what information has been viewed by the user).

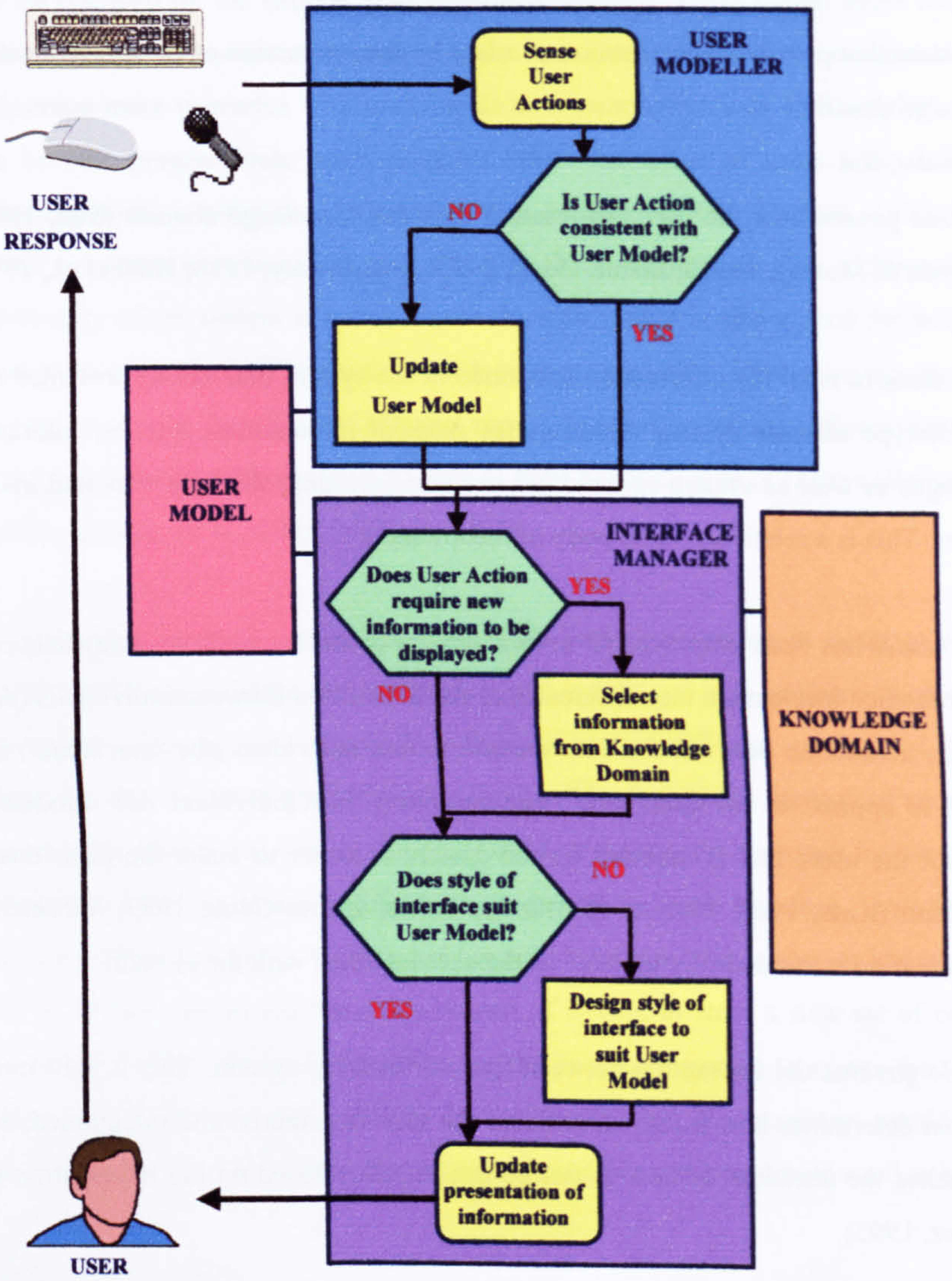


Figure 1: The interaction between the components of an adaptive system

The *interface manager* assesses the user action to determine whether new information has to be displayed to the user. If "yes", then the appropriate information is selected from the *knowledge domain* (such as the next piece of information to display within a tutorial sequence). The *interface manager* then consults the updated *user model* to determine which style of presentation best suits the user (e.g. whether the user would understand the information better if it was presented using text, audio or images, or whether they would understand the information better if it was displayed in one large chunk or in a number of smaller steps). The *interface manager* finally updates the presentation of information to the user through the visual display or speakers.

The new presentation of information induces a new user response that is fed back into the system through the keyboard, mouse or microphone, which in turn influences the way the next piece of information is presented.

To ensure that correct decisions are made by the system, it is important to identify what are the user characteristics that are needed by the system in order to make the appropriate adaptation decisions. These characteristics will be stored in the *user model*. Individuals vary in an infinite number of ways so it is not possible to model a large number of characteristics for each user. However, it may be possible to identify the aspects of the user that are required by the system to make the necessary adaptation decisions (Self, 1988; Allen, 1990; Elsom-Cook, 1993; McTear, 1993). The information that is needed by an application in order to adapt itself to individual users varies from application to application, however, a core of frequently used attributes have been established (Finin, 1987; Benyon & Murray, 1993a; Elsom-Cook, 1993; McTear, 1993; Brusilovsky, 1996; Averbukh, 1997; Milne et al., 1997; Conati & VanLehn, 2001):

- The user's goals. These define the state that the user wants to achieve, such as performing a specific action or obtaining specific knowledge, which depends on the context of the user's work. Examples include long term educational goals or problem-solving goals which may change from session to session.
- The user's current state of knowledge. This is an estimation of what the user knows of certain concepts, including capabilities, and level of understanding. This is required in order for the system to judge the user's ability to perform an action or to generate responses in terms that the user would understand. The system should be able to record whether the user knows or does not know about a particular concept. This could range from a detailed record of individuals in a student model (Benyon & Murray, 1993b) to an overall stereotype assessment of a group of users (Beaumont, 1994; Hohl et al., 1996).
- The user's background and experience. This may include the user's previous experience outside the system such as their profession, or experience of work in related areas.
- User preferences. These are the users' choices of the adaptable aspects of the system which range from colour schemes to areas of personal interest that cannot be deduced by the system but have to be explicitly stated by the user.

The term *user modelling* has been applied to this process of gathering information about users in order to provide services or information that are adapted to the specific requirements of individual users, or groups of users (McTear, 1993). The modelling components have the responsibility of constructing the user model, storing, updating and deleting entries while maintaining the consistency of the model, and supplying other components of the system with relevant information about the user. Maintenance activities involve interpreting new knowledge about the user, triggering inferences to add new facts to the model, and resolving any inconsistency. A static user model would be inadequate as the user's state of knowledge is continually changing as they interact with the system, therefore parts of the model have to be updated dynamically.

The information that is contained in the *user model* can be extracted explicitly from the user in a long series of complex questions before the session starts, or inferred by the *user modeller* analysing the user's actions (Finin, 1987; Chin, 1989; McTear, 1993; Srinivasan & Scherbakov, 1995). Explicit information comes from a source that is external to the system which is usually the users themselves. However, the results from question and answer sessions are not always reliable, as the users may not possess the skills to provide the required level of self-estimations. Also it may be daunting for the user to start the dialog with the system by answering a long series of detailed questions (McTear, 1993; Fischer, 2001). Explicit information may also come from the system designer in the form of stereotypes. A stereotype is a previously defined collection of general traits or characteristics that belong to an identifiable group of users. When a user is identified as belonging to a stereotypical group all the information contained in the stereotype can be included in the individual's user model (Bocker et al., 1990; Beaumont, 1994; Hohl et al., 1996; Hook, 2000). The *user model* containing the stereotype can be refined by adding specific information relevant to the individual user (McTear, 1993).

Implicit information is acquired by the system without explicitly consulting the user, by analysing and applying inference rules on information that is already available within the *user model*. Information can be deduced about the user by monitoring and analysing the their actions during the session, such as time taken to perform tasks, the path the user takes through information, number of errors, etc. (Finin, 1987; Chin, 1989; McTear, 1993; Srinivasan & Scherbakov, 1995; Fischer, 2001).

There needs to be a balanced approach between the implicit and explicit gathering of information about the user. It is possible to infer information such as goals from user actions (such as identifying the information they are searching for) but there should be an opportunity for users to inspect the information contained in their *user model* and make modifications (Kuhme, 1993; Hook, 1996; Ferri & Grifoni, 2000; Hook, 2000). Explicitly gathered information is likely to be much more reliable than implied information and is less likely to change in the short term (Self, 1988; Fischer, 2001).

1.1.4.3 Research into adaptive systems

The majority of research into adapting the presentation of information has been in the areas of *educational hypermedia* and *on-line information systems* (Brusilovsky, 1996; Brusilovsky, 2001). The main differences between the two types of system are the goals of the user and the nature of the information space.

Educational hypermedia is concerned with the delivery of specific sets of information to students. The goals of users are to learn about the information and so the most important attribute of users that govern the interaction is the user's state of knowledge. The state of knowledge can vary greatly between users, and the knowledge of individual users can change quickly. Advanced students may become bored if they are presented with information they already know while novice users may easily become lost in the information space. Therefore the aim of adaptive educational systems is to select the appropriate educational information that matches the goals and knowledge of the students.

Most of the early research projects such as *Hypadapter* (Bocker et al., 1990, Hohl et al., 1996), *Anatom-Tutor* (Beaumont, 1994), *C-Book* (Kay & Kummerfeld, 1994), *ISIS-Tutor* (Brusilovsky & Pesin, 1994) and *HyperTutor* (Perez et al., 1995) were concerned with stand-alone systems that contained pre-defined sets of tutorial information. However, most of the more recent research projects such as *Arthur* (Gilbert & Han, 1999), *ELM-ART* (Brusilovsky et al., 1996; Webber & Specht, 1997), *Hy-SOM* (Kayama & Okamoto, 2001), InterBook (Brusilovsky et al., 1998), *TANGOW* (Carro et al., 1999) and *ART-Web* (Webber, 1999) are more concerned with the delivery of information using the World Wide Web. These systems are not only concerned with the presentation of pre-defined sets of information but also in guiding users to information on the World Wide Web outside the control of the developers of the system.

The main problems with the *educational hypermedia* systems are the way they deal with the knowledge of the user. It is difficult to assess the knowledge of users as the knowledge of different users can vary greatly and the knowledge of individual users can grow quite fast over the course of a tutorial session. An individual page can be incomprehensible to a novice and at the same time trivial and boring for an advanced learner. The fact that the system has presented certain information to users does not guarantee that the user has understood it. Although it is possible for the system to support users in their chosen route through the tutorial information novices may not be able to make informed decisions about the path to follow through the information (Brusilovsky, 1996; Brusilovsky, 2001).

On-line information systems are similar to the *educational hypermedia* systems except users have different goals relating to the retrieval of specific pieces of information within large information spaces rather than learning about a wide body of information. Adaptive *on-line information systems* attempt to adapt the presentation of information in a manner that enables users to access their required information efficiently.

Published research into *on-line information systems* include systems such as *Ecran Total* (Geldof, 1998), *ELFI* (Schwab et al., 2000), *HYPERCASE* (Micarelli & Sciarrone, 1996), *HYPERFLEX* (Kaplan et al., 1993), *PUSH* (Hook et al., 1996) and *SWAN* (Garlatti et al., 1999). Other systems include information kiosks such as *AVANTI* (Fink et al., 1998) and electronic encyclopaedias such as *PEBA-II* (Milosavljevic, 1997; Signore et al., 1997; Hirashima et al., 1998).

Adaptive *on-line information systems* have similar problems to adaptive *educational hypermedia* systems as it is difficult to assess the knowledge of different users. An additional constraint is time, as unlike students of *educational hypermedia* users don't always have the time to browse through all the information about a concept to find the portion of information they require. Also it is particularly difficult for adaptive *on-line information systems* to assess the user's goal. In *educational hypermedia* systems users have a relatively easily identifiable educational goal which is not so apparent for users of adaptive *on-line information systems* unless users directly state it (Hook et al., 1996).

Both *educational hypermedia* and *on-line information systems* have direct relevance for the development of the prototype telecare system. One aspect of the prototype system is providing medical information which may be in the form of tutorials (such as how to measure blood pressure) or to allow users to browse for specific information of their own interest. The existing principles of making systems adapt to individual users were applied to these features of the prototype while original research was conducted on the effect of adapting the interface to suit different types of user.

- Research into *educational hypermedia* and *on-line information systems* have concentrated on two types of adaptivity (Brusilovsky, 2001):
- *adaptive presentation* (changing the information that is displayed), and
- *adaptive navigation* support (changing the path that users follow through the information space).

Adaptive presentation involves changing the content of the information to suit individual users. Users with different knowledge of a particular concept may need structurally different explanations about the concept, therefore the information content may have to be changed (Paris, 1988). Different research projects have developed different techniques of adapting the information content. For example, *Anatom-Tutor* (Beaumont, 1994) and *C-Book* (Kay & Kummerfeld, 1994) use the *explanation variants* technique which requires tutors to produce a number of different versions of the same information content that are suitable for different user stereotypes. This technique places greater demands on the developers of the system who have to prepare a number of different versions of the same information. Pieces of information are relatively large within each section and there is no mechanism for adapting to individual differences other than pre-defined stereotypes of user. A more powerful method is the *frame-based* technique as used in *Hypadapter* (Bocker et al., 1990; Hohl et al., 1996) and *PUSH* (Hook, et al., 1996) where information is divided into smaller sections. All information about a concept is represented in the form of a frame, and slots within the frame can contain several *explanation variants* suitable for different categories of user. The information to be presented to individual users is determined by a series of *topic selection rules*, and the way the material is presented is determined by a series of *presentation rules* (which corresponds to the *interface management* component in figure 1).

Adaptive navigation involves providing assistance to enable users to select their route through an information space. Techniques include dividing the same information into smaller steps, or re-ordering the sequence in which the information is presented (Karagiannids et al., 1996). Links can be sorted into order of importance and irrelevant links can be hidden (Perez et al., 1995). Another method is to allow the system to select the next piece of information to present to the user (Bocker et al., 1990; Hohl et al., 1996). This method may provide users with direct guidance but cuts down the users' control of the system (Brusilovsky, 1996).

In order to investigate the issues involved in building adaptive systems the prototype telecare system was designed to adapt aspects of the interface to suit the needs of individuals. There were a number of aspects of the interface that could be adapted, including:

- the selection of medical or general information,
- the selection of information about the system to help the user operate the system,
- the style of user instructions,
- how the user inputs information (e.g. using the mouse rather than the keyboard), and
- how the system outputs information (e.g. displaying an image rather than text).

The information providing aspects of telecare are similar to both the *educational hypermedia* and *on-line information systems* and so the prototype system was designed to implement an adaptive mechanism that followed the same principles illustrated by figure 1.

1.1.4.4 Areas of adaptive systems that require further research

There are a number of challenges for developers of adaptive systems including:

- Establishing usability principles for adaptive systems.
- Measuring the usefulness of adapting systems to suit individual users (quantifying the benefits to individual users of presenting an adaptive interface).
- Investigating attributes of users that the interface should adapt to.

New usability principles need to be developed as the operation of adaptive systems often violate the established usability principles of *consistency* and providing the user with a sense of control over the system (Hook, 2000). The output of adaptive systems cannot always be predicted and may be unexpected and confusing for the user. The processes that the system perform in making the decisions of what to display to the user is not transparent which may make users feel they are not in control of the system.

It is important to measure the benefit of adapting the interface to suit individuals in order to make an assessment of the value of devoting the effort into developing adaptive systems. Often adaptive systems have expensive mechanisms in terms of development and processing time that achieve minimal improvements in usability and usefulness (Fischer, 2001).

There has been research into adaptive systems using user models since the mid 1980s, however the benefits of adapting systems have not been established. In a review of literature over a nine year period in one journal (*User Modeling and User-Adapted Interaction*) the majority of papers on adaptive systems were descriptive, and only 25% included any significant empirical evaluations. Most presented preliminary results, pilot studies or do not include enough participants to produce statistically significant results. The same review highlighted the need to assess the benefits of adaptivity in a manner that were separated from confounding factors and proposed a framework for assessment and reporting standards including the statistical significance of the analysis (Chin, 2001).

Research also has to take place into the characteristics of the user that the interface should be adapted to suit. One set of user attributes that require further investigation are the cognitive aspects of the user. There has been a debate about the extent of the contribution that cognitive psychology can make to the field of human-computer interaction. Despite early optimistic predictions about the benefits that can be derived from designing interfaces to suit the cognitive processes of individuals the design of most interfaces are more influenced by the issues involved in programming (Green et al., 1996). A number of experiments have attempted to adapt interfaces to suit the users' learning style (Carver, et al., 1996; Danielson, 1997; Specht &

Opperman, 1998; Gilbert & Han, 1999), however it is not clear which aspects of learning style are worth modelling and what can be done differently for users with different styles (Brusilovsky, 2001).

Before usability principles can be established the usefulness of adapting the interface needs to be investigated, which requires the identification of user attributes that the interface should be adapted to suit. The effect of adapting the interface to suit the cognitive processes of individuals was identified as an area that required further research, therefore the nature of cognitive style is discussed in the following section.

1.1.5 Adapting systems to cognitive style

In this section the many definitions of cognitive style (CS) are explored. The classification of CS used in the Cognitive Styles Analysis (CSA) program (Riding, 1991; Riding, 1998) was chosen as the definition of CS used in the experiments performed for this thesis. The experiments that used the CSA classification of CS performed by other researchers described in published academic journals are discussed. The experiments using the CSA classification performed for this thesis are discussed in chapters 4 to 8.

1.1.5.1 Definitions of cognitive style

A CS is the consistent underlying method of an individual's thinking and perceiving that subsequently affects the way in they perceive and respond to events and ideas (Tennant, 1988; Riding, 1991; Riding & Cheema, 1991; Riding, 1994; Riding, 1997; Riding et al., 1997; Riding & Staley, 1998).

The term *cognitive style* is distinct from the term *learning style* as the former refers to a *fixed* way of perceiving while the latter refers to a temporary strategy that is adopted to process new concepts (Rayner & Riding, 1997).

There is a wide range of different labels and methods of measuring CS (Kotteman, 1988; Riding & Cheema, 1991; Green et al., 1994; Rayner & Riding, 1997). Riding and Cheema (1991) reviewed over 30 methods of defining CS and concluded most could be grouped within two fundamental independent CS dimensions while the remaining definitions described learning strategies.

The first group of measures included *field dependence-independence* (Witkin, 1962; Witkin et al., 1971), *impulsivity-reflectivity* (Kagan, 1965), *convergent-divergent* thinking (Hudson, 1966), *leveller-sharpener* (Holzman & Klien, 1954) and *holists-serialists* (Pask & Scott, 1972). The main similarity between these measures was that they all assess the way individuals process information. *Field dependence-independence* measures the degree to which individuals rely on the *field* or context to make sense of information. *Impulsivity-reflectivity* measures the rate at which individuals make decisions under conditions of uncertainty. *Convergent-divergent* thinking classifies individuals by their preference for formal structured problems or more open-ended problems that require creativity. The *leveller-sharpener* measure classifies individuals by the method in which they store new events in memory, either as discrete events or associated with other related events. The *holists-serialists* measure classifies individuals by the way they solve problems, either by looking for patterns in large amounts of information or by processing smaller amounts of information in a step-by-step approach.

The second group of measures was concerned with the differences in the way individuals represent information while thinking (i.e. whether they think in terms of words or use mental images). The three main measures were the *Individual Differences Questionnaire* (Paivio, 1971), the *Verbaliser-Visualiser Questionnaire* (Richardson, 1977) and the *Verbal-Imagery Code Test* (Riding & Calvey, 1981). Each test compared the preferences and abilities of individuals in tasks that involved the verbal presentation of information with a presentation that used images.

The relationship between each of the different measures of CS were examined by comparing the correlation between the scores that individuals achieved in the tests associated with each measure (Riding & Dyer, 1983). The test results of individuals were closely correlated within each group of measures but there was no correlation between the results of measures in other groups. From this it can be concluded that there are two fundamental dimensions which are independent of each other. For example, an individual's position along one dimension is not dependent on their position along the other. The first grouping (Wholist-Analytic dimension) related to whether the individual processes information in wholes or in parts and the second grouping (Verbal-Imagery dimension) relates to whether the individual is inclined to represent information using mental pictures or words (Riding & Cheema, 1991; Riding & Rayner, 1998).

1.1.5.2 The Wholist-Analytic and Verbal-Imagery dimensions of cognitive style

A person's position along the Wholist-Analytic dimension reflects whether they understand situations as a whole or see things in parts, while their position along the Verbal-Imagery dimension reflects the manner in which they represent information while thinking, either as words or mental pictures or images (Riding, 1991; Riding, 1996; Riding, 1997; Riding, 1998).

The Wholist-Analytic and Verbal-Imagery groupings of style are represented as the independent dimensions shown in figure 2.

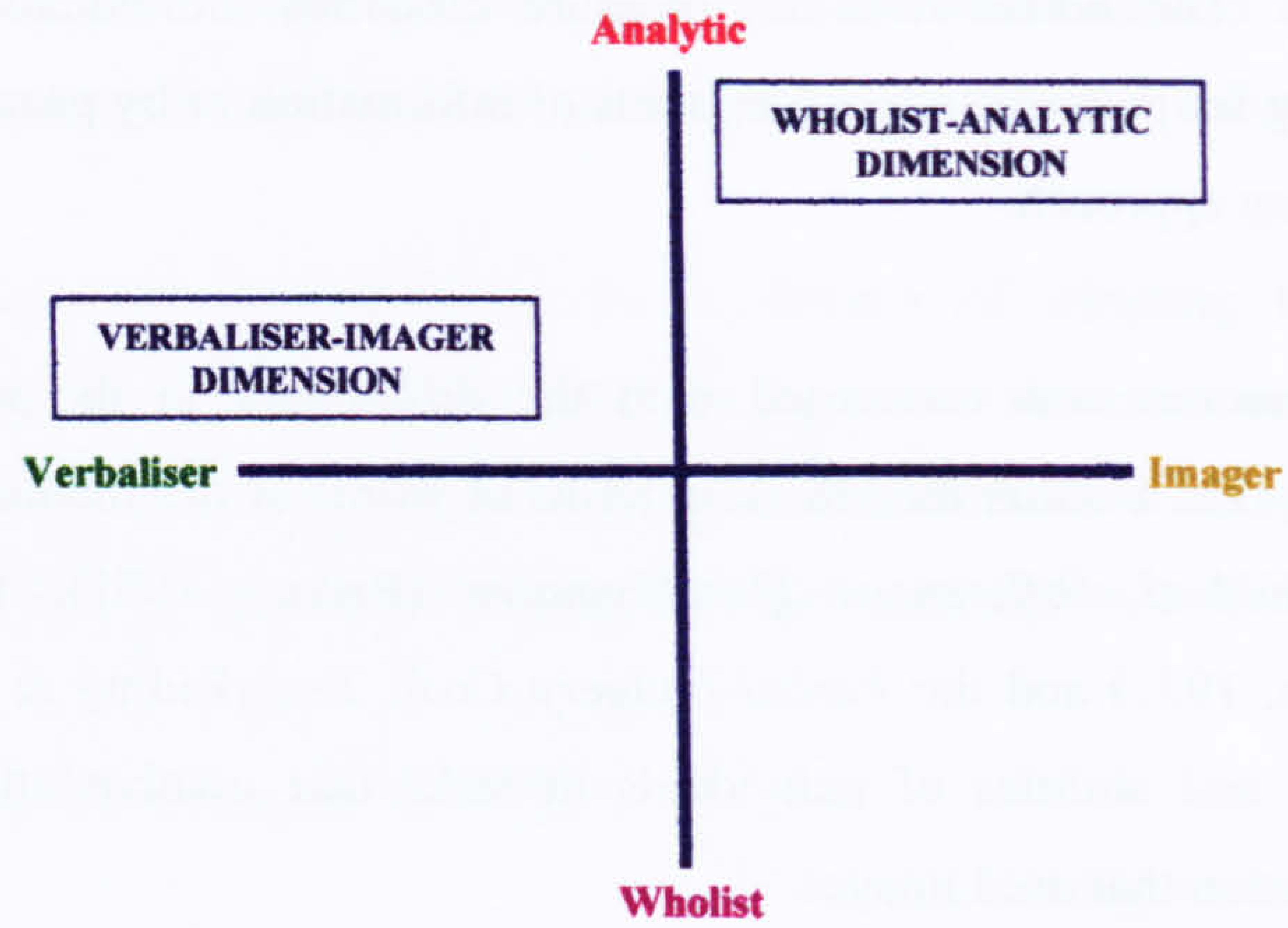


Figure 2: The two cognitive style dimensions

The characteristics of each CS (Wholists, Analytics, Verbalisers and Imagers) determine the way individuals perform in social situations (whether they are outgoing or more restrained), at work situations (whether they prefer to organise tasks themselves or prefer to be organised by others) as well as how individuals perceive and respond to information. This thesis is more concerned with the way individuals perceive and structure information than the social interaction issues.

The Wholist-Analyst dimension determines whether people understand information or situations as a whole, or see things in parts. Wholists tend to view a situation as a whole and have an overall perspective. New information is stored serially in the brain as loosely clustered wholes rather than associated with related information that is already known.

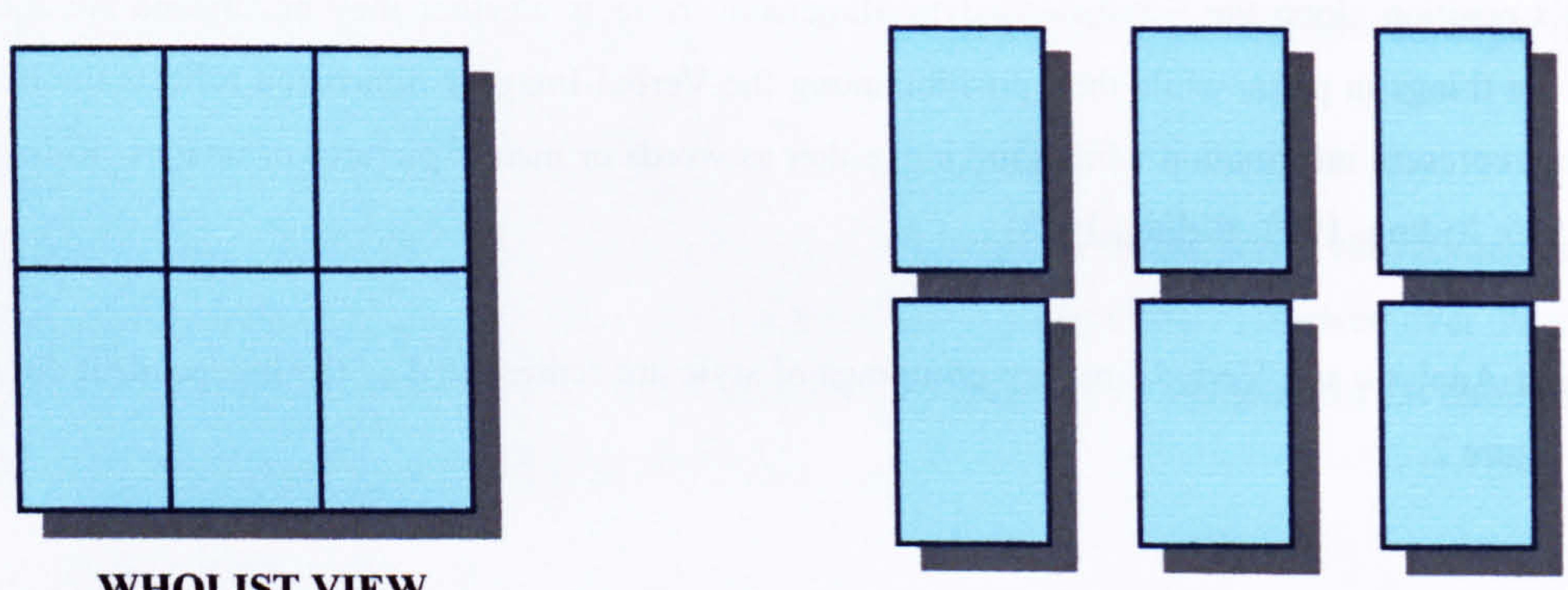


Figure 3: The difference between the Wholist and the Analytic View

Analytics will tend to view a situation as a collection of parts, and will often focus on one or two aspects at a time to the exclusion of the others. Analytics separate out new information into conceptual groupings and store it in relation to what they already know. Socially, Analytics will tend to view a social group as a collection of individuals. The difference in perspective of Wholists and Analytics is illustrated in figure 3.

The positive aspect of the Wholist view is that Wholists are able to appreciate information in its total context and can have a balanced view. This will make it less likely that they will have extreme views or attitudes.

The negative aspect of Wholists is that they have difficulty in separating a situation out into its parts, which may lead to an indistinct or blurred view of the details. The positive aspect of the Analytic view is that they have a stronger understanding of the individual parts of a situation. The negative aspect of Analytics is there is a danger that the relative proportions of each part of a situation may become distorted. Figure 4 illustrates these negative aspects of a blurred Wholist view or a distorted Analytic view.

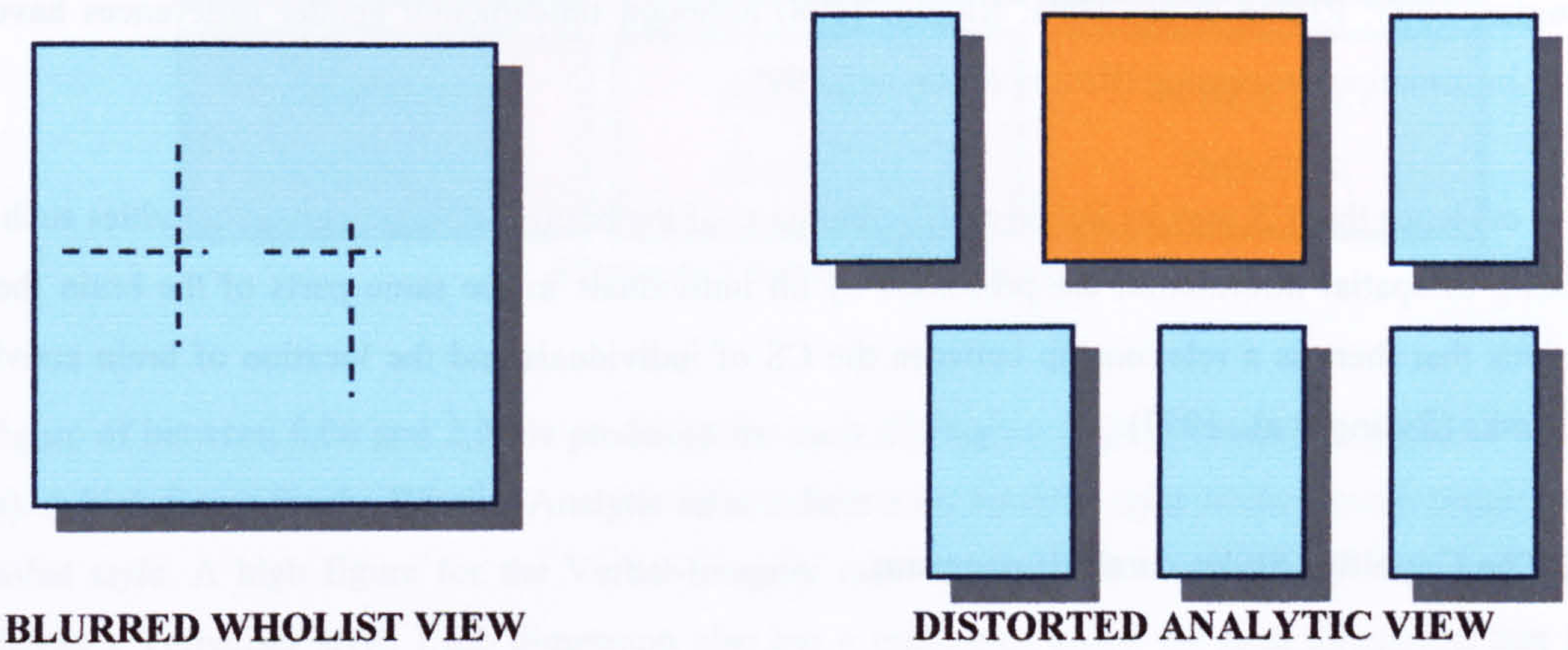


Figure 4: Negative aspects of the Wholist and the Analytic Views

The Verbaliser-Imager dimension determines the characteristic mode in which individuals represent information while thinking and the way they relate to social groups. Verbalisers consider the information they see, read or listen to, primarily as words or verbal associations (Verbaliser in figure 5). As speech is the basic medium of communicating with others, Verbalisers have an in-built advantage in social situations compared to Imagers and tend to be more out-going and socially aware.

When Imagers read, listen, or consider information they experience fluent, spontaneous and frequent mental pictures (Imager in figure 5). The style of Imagers has more to do with a world internal to the individual than with communicating with others and so Imagers tend to be more inward-thinking and less socially aware than Verbalisers.

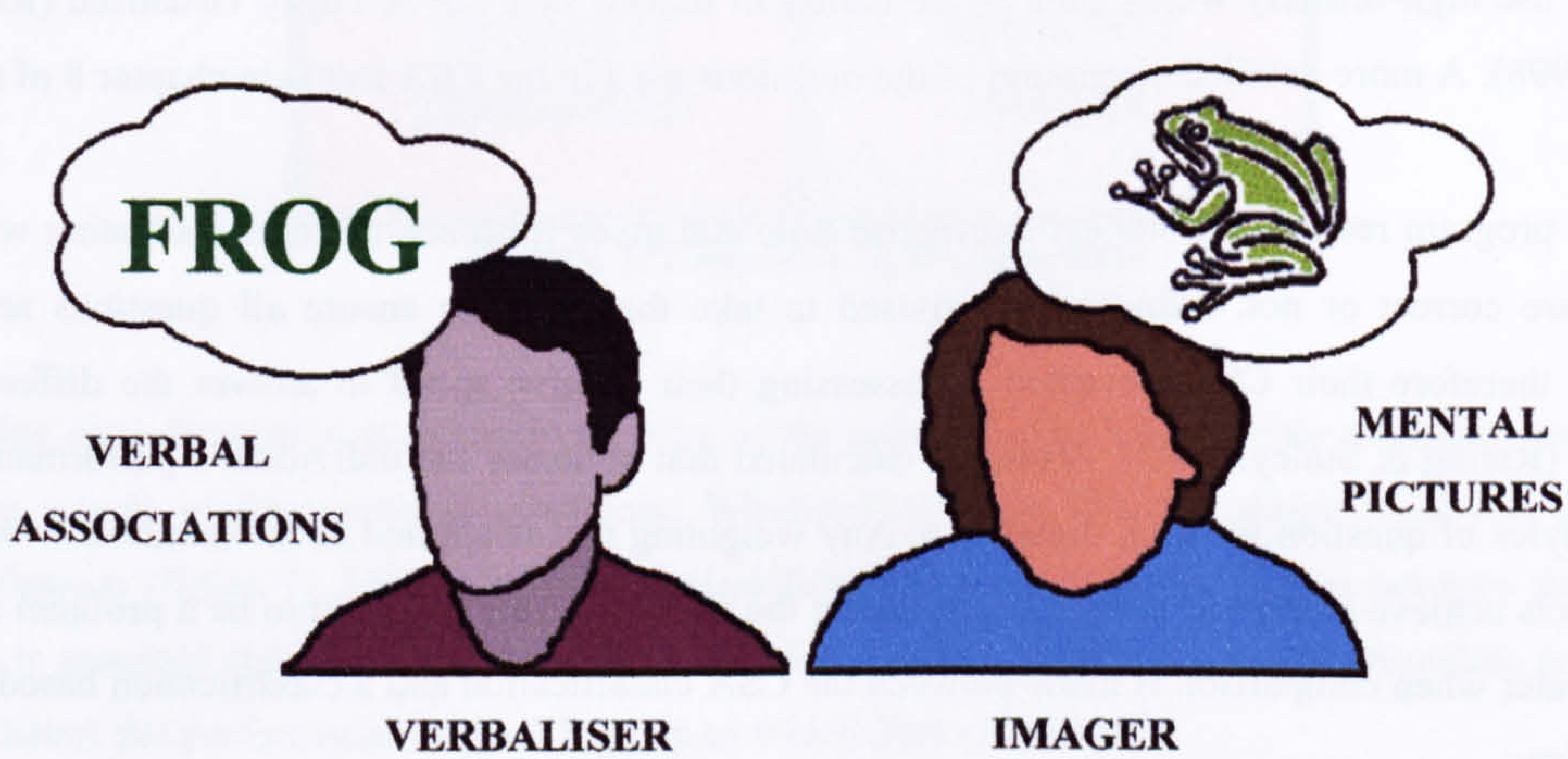


Figure 5: Verbaliser & Imager mode of representing information

These CSs have been shown to be distinctly separate from personality, intelligence or gender. When measuring the performance of subjects in tests there was low correlation between the CS of subjects and basic personality dimensions, such as *introversion-extroversion* and *stability-neuroticism* (Riding & Wigley, 1997), measures of intelligence (Riding & Pearson, 1994; Riding & Agrell, 1997) or age (Riding & Wheeler, 1995; Riding, 1997). Gender was not found to have a significant influence on the CS of individuals (Riding & Douglas, 1993; Riding et al., 1995; Riding, 1998) although fundamental gender differences have been found in information processing (Riding & Rayner, 1998).

There is evidence that CS may be linked to different parts of the brain. Although certain activities such as the processing of spatial information are processed by all individuals in the same parts of the brain there are indications that there is a relationship between the CS of individuals and the location of brain activity for certain tasks (Riding et al., 1997).

1.1.5.3 The Cognitive Styles Analysis program

The Cognitive Styles Analysis (CSA) program was produced by Birmingham Learning and Training Technology (Riding, 1991; Riding, 1998) in order to automatically calculate the CS of individuals in terms of their Wholist-Analytic and Verbal-Imagery dimensions. A person's position along each dimension is assessed by their performance when subjected to a series of simple questions, half of which are designed to suit the characteristics of one style and half are designed to suit the opposite style.

The questions that assess the classification of the Wholist-Analytic dimension use graphical images. The Wholist style questions ask the subjects performing the test to identify differences in the overall appearance of objects while the Analytic style questions ask subjects to identify whether simple objects were contained within other more complex objects. The questions that assess the Verbal-Imagery classification of subjects use simple statements comparing pairs of words. Subjects are asked to determine whether they were *true* or *false*. Verbaliser style questions use the names of concepts, such as sports or careers while the Imager style questions use high-imagery words such as the names of objects that can be easily visualised (Riding, 1991; Riding, 1998). A more detailed discussion of the questions used in the CSA test is in chapter 8 of this thesis.

The CSA program records the subject's response time and gives feedback to them, indicating whether their answers are correct or not. Subjects are advised to take their time to ensure all questions are answered correctly, therefore their CS is revealed by assessing their relative speed to answer the different style of questions (Riding & Staley, 1998). A ratio is calculated that indicates the individual's performance between the two styles of question for each dimension. Any weighting that is applied to the duration or score figures that subjects achieve in the test are not disclosed by the software. This turns out to be a problem as it will be revealed later when comparison is made between the CSA classification and a classification based on original experiments.

Figure 6: Cognitive style groups

A figure of between 0.00 and 2.00 is produced for each dimension (higher values are possible but they are rare). A high figure for the Wholist-Analytic ratio indicates an Analytic style while a lower figure indicates a Wholist style. A high figure for the Verbal-Imagery ratio indicates an Imager style while a lower figure indicates a Verbaliser style. Each dimension also has a mid-range group for each dimension that indicates subjects performed equally well in both styles of question. Using these figures individuals are classified as belonging to one of nine possible categories of CS (figure 6). Three categories are defined along the Wholist-Analytic dimension (Wholist, Intermediate and Analytic) and three categories are defined along the Verbal-Imagery dimension (Verbaliser, Bimodal and Imager).

In experiments this classification is often simplified to produce four CS groups as shown in figure 7 (Riding & Sadler-Smith, 1992; Riding & Read, 1996).

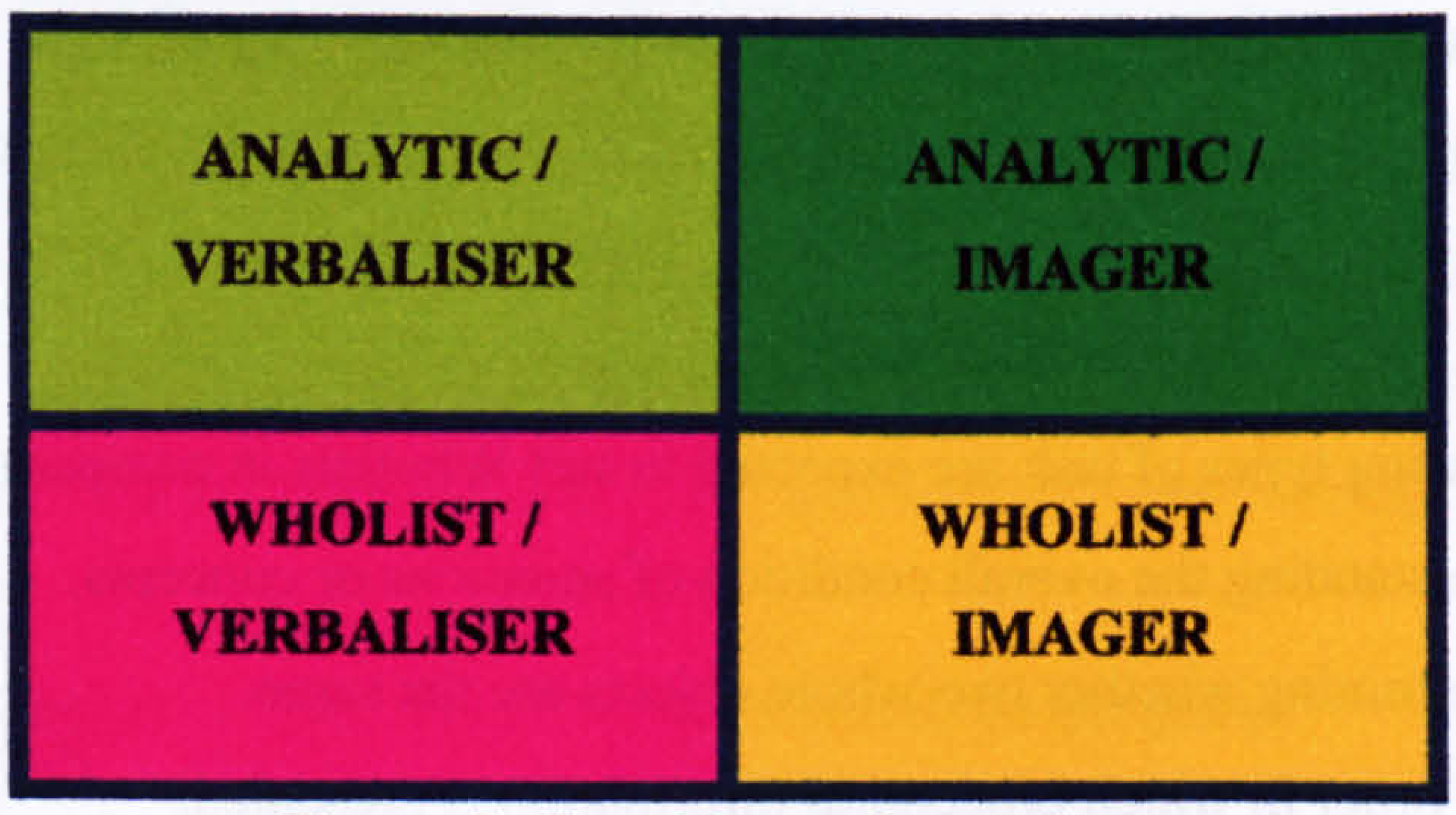


Figure 7: Cognitive style quadrants

By dividing each dimension at the halfway point of the middle group it is possible to classify individuals as belonging to one of four possible quadrants; Wholist/Verbaliser, Wholist/Imager, Analytic/Verbaliser or Analytic/Imager (figure 7). This simplifies the classification and makes comparisons between the CS groups easier. It is assumed that the performance of individuals in the middle groups (Intermediate and Bimodal) will not distort the performance of the CS group to which they are assigned.

The performance of groups of users can be measured in a number of ways, by comparing the performance of Wholists against Analytics regardless of their Verbal-Imagery classification, by comparing the performance of Verbalisers against Imagers regardless of their Wholist-Analytic classification or by comparing each CS quadrant against each other, as illustrated diagrammatically in Table 1.

	Comparing the characteristics of Wholists against Analytics without reference to their Verbal-Imagery classification.
	Comparing the characteristics of Verbalisers against Imagers without reference to their Wholist-Analytic classification.
	Characteristics of all four quadrants against each other (Wholist/Verbalisers, Wholist/Imagers, Analytic/Verbalisers and Analytic/Imagers).

Table 1: Key for cognitive style group comparisons

Throughout this thesis the symbols shown in table 1 are used to indicate where the different types of comparisons are being discussed.

1.1.5.4 Expected performance of individuals within each cognitive style

This section discusses the expected performance of individuals within each of the CS groups. These expectations were derived from the literature associated with the CSA test and were used as a basis for testing performance of subjects in the experiments described later in this thesis.

The following types of task are expected to suit Wholists in comparison to Analytics:

- Understanding the overall condition of situations or concepts.
- Determining whether two whole objects are the same.
- Remembering the order in which procedural information is presented.

Wholists would benefit from information being structured in a manner that emphasises the distinctive aspects of the parts that make up the whole. This may involve cutting the information up into smaller steps so that no detail will be missed or emphasising the distinctive aspects of each section with use of *organisers* such as headings (Riding, 1991; Riding, 1994; Riding, 1996; Riding & Sadler-Smith, 1992).

The following types of task are expected to suit Analytics in comparison to Wholists:

- Answering comprehension questions about the details of information rather than the whole.

- Identifying which shapes make up a whole shape or object.
- Answering mathematical questions.
- Making sense of geographical or spatial information.

Analytics separate out tasks into their parts, or sections and so would benefit from being provided with an overview to ensure they do not miss the context of the details (Riding, 1991; Riding, 1994; Riding, 1996). The use of different media to present information is not expected to favour either Wholists or Analytics.

The following types of task are expected to suit Verbalisers in comparison to Imagers:

- Tasks based on the understanding of information that is presented using text (text based comprehension questions).
- Determining the difference between two concepts rather than objects.
- Understanding information that is presented procedurally.
- Answering mathematical questions.

Verbalisers learn better by reading text than looking at diagrams or images and so information should be presented wherever possible in text format. Facts should be presented procedurally or as a list of points (Riding et al., 1989; Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1998).

The following types of task are expected to suit Imagers in comparison to Verbalisers:

- Understanding information that is presented using diagrams or images.
- Making comparisons between objects rather than concepts.
- Understanding spatial information including maps.

Imagers generally learn best from pictorial presentations and so information may need to be represented in diagrammatic form where possible. It may not always be possible to display equivalent information of a piece of text using only images and so any accompanying text should contain visually-rich descriptions (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1998; Riding et al., 1989; Riding & Sadler-Smith, 1992).

1.1.5.5 Experiments that have used the Cognitive Styles Analysis program

This section reviews a number of experiments that have tested the expected performance of each CS group with their actual performance. These include experiments conducted by the author of the CSA test and those conducted independently.

A number of experiments compared the performance of subjects in tasks that were structured to suit Wholists or to suit Analytics. Positive interactions between CS and performance were found where subjects who were classified as Wholists by the CSA test perform better at Wholist style tasks and subjects who were classified as Analytics perform better at the Analytic style tasks. One experiment compared performance of subjects in tasks that presented the title of a piece of prose in different locations. The Wholist subjects performed best when the title of a passage of prose was given before the passage was presented while there was little effect for Analytic subjects whether the title was presented before or after (Douglas & Riding, 1993).

A number of experiments assessed the effect that the Verbal-Imagery classification of subjects had on their performance in tasks using different modes of presenting information. Positive interactions between CS and performance were found where subjects who were classified as Verbalisers by the CSA test perform better at Verbaliser style tasks and subjects who were classified as Imagers perform better at the Imager style tasks. The Verbaliser style tasks presented text while the Imager style tasks presented equivalent images. The performance of Verbaliser subjects was greater in the Verbaliser tasks than the Imager style tasks and the performance of Imager subjects was greater in the Imager style tasks than the Verbaliser style tasks (Riding & Ashmore, 1980; Riding et al., 1989). Similar interactions were found where the presentation of text was mixed with images. The Verbaliser style tasks contained purely text while the Imager style tasks contained text plus images (Riding & Douglas, 1993). Similar interactions were also found that depended on the type of content of text. The Verbaliser style task used text that contained a high level of acoustic and semantic complexity while the Imager style task used text that contained a high degree of visual imagery (Riding & Calvery, 1981).

The Wholist-Analytic classification combined with the Verbal-Imagery dimension was also found to affect the perception of subjects depending on the conceptual structure of information depending on the amount of information that is presented in each step, and the presence or absence of an overview. The performance of subjects was found to depend on the CS quadrant that subjects belonged to, e.g. Wholist/Verbalisers and Analytic/Imagers performed least well when large amounts of information was presented in each step but improved when less information was presented in each step. In contrast Analytic/Verbalisers performed best when large amounts of information was presented in each step (Riding & Sadler-Smith, 1992).

In other experiments the CS of subjects has also been found to correlate with their preferred format of learning material, with the majority of Verbalisers choosing verbal presentations and the majority of Imagers choosing pictorial presentations (Riding & Watts, 1997; Riding & Reed, 1996).

Other researchers have also conducted experiments using the CSA test and found differences in the behaviour of different CS groups. Wood et al., (1996) found significant differences in the strategies adopted by subjects searching databases. Wilkinson et al., (1997) found a difference in the way subjects with different CSs retrieved information from large textbooks compared to the same information presented in hypertext format. Boles and Pillay (1999) did not find significant differences between the performance of different CS groups using computer-based instruction material (CBI) but found enough evidence of different patterns of behaviour to recommend tailoring of CBI material to match the style of individuals. Atkins et al., (2001) proposed a framework using the CSA test for investigating the influence of learning styles based on text-based computer conferencing, although no findings have yet been reported.

1.2 Contributions to knowledge of the thesis

The contributions to knowledge of this thesis fall into three main areas:

1. The innovations built into the prototype telecare system
2. The identification of the sort of tasks and the types of media that will result in each cognitive style group achieving greatest performance.
3. The proposal of a new dimension to the definition of cognitive style that classifies individuals by the way they perform when presented with visual information compared to auditory information.

The prototype telecare system was built to demonstrate existing usability principles and methods used in adaptive systems, however the system is unique and contains a number of innovations associated with the application of the technology used to build the system, how information is structured, and the design of the style of interaction:

- The design of the screen layout. The design of the objects on the screen and the particular mix of media used to present information and methods of receiving input from the user.
- The design, functionality and operation of the option and command buttons.
- The animated menu bar that is available throughout the system.
- The configuration of the videophone facility. A camera is set to take pictures every two seconds and a web server on the local machine makes the saved images available over the Internet. Images from the remote machine are repeatedly requested by the local machine using a web browser built into the system.
- The method of browsing the Internet. Internet hyperlinks contained in each new HTML page are extracted and are associated with command buttons that allow the user to browse the Internet using a small set of voice commands.
- The use of the companion personality throughout the system.
- The strategy used to adapt the system. The underlying mechanism for adapting the system uses existing principles, but the system structures the information in a unique manner and uses a unique set of user attributes to adapt the system.

A major contribution to knowledge was the identification of the sort of tasks and types of media in which each cognitive style group achieved greatest performance:

- A new measure is used to assess performance. A performance ratio is calculated by dividing the percentage of questions subjects answered correctly by the mean duration that subjects took to answer one question. For individuals to achieve a high performance ratio they have to score high in a short duration.
- For each task ranking tables are produced showing the relative performance of the cognitive style groups.
- For each cognitive style group ranking tables are produced showing their relative performance between the tasks.
- This information can be used by developers of multimedia systems in order to develop interfaces that would enable each cognitive style group to improve their performance. For each cognitive style group

interfaces should be developed that contain the types of activities and media that are contained in the high ranked tasks and less of the activities and media that are contained in the low ranked tasks.

The main contribution to knowledge of the thesis is the proposal of a new dimension to the definition of cognitive style that classifies individuals by the way they perform when presented with visual information compared to auditory information.

- A new definition of CS is proposed that consists of a visual Wholist-Analytic dimension, an audio Wholist-Analytic dimension, a visual Verbal-Imagery dimension, and an audio Verbal-Imagery dimension.
- An individual's classification can be calculated using the existing CSA package augmented by the new audio test.

1.3 Summary

This chapter reviewed the background information relevant to the development of the theme of this thesis. The thesis is concerned with creating easy-to-use interfaces for telecare systems that enable communications and assists users to access information. Furthermore the thesis is concerned with investigating the surrounding issues such as how to adapt the system to suit the CS of users. This chapter has explored the nature of telecare, and the method of organising information using hypermedia and how computer systems are able to adapt aspects of the interface to suit individual users. CS was identified as an attribute of individual users that the system should adapt itself to suit. Therefore the nature of CS was investigated in more detail, including the definition of CS, how CS can be measured using the CSA test and what effect has CS on the performance of individuals in different styles of task. The original contribution to knowledge of this thesis lies in the innovations built into the prototype telecare system and the investigation into the use of CS as an attribute of users that the system should adapt itself to.

The next chapter defines the requirements of a prototype telecare system and describes the system that was implemented.

2. The Telecare Companion prototype

The aim of this thesis is to investigate methods of providing intelligent assistance to users of telecare and multimedia computer systems. As part of this investigation a prototype telecare system was developed to demonstrate an easy-to-use interface. This chapter describes the development of the prototype, named *Telecare Companion*. First the requirements of the system are described, including who the target users are, and what are the communication and information requirements. Next the technologies used for the development of the prototype are described. Lastly the prototype system that was built is described, highlighting the features that make the system easy-to-use. Only the static features are described in this chapter, while the dynamic adaptive features are described in the next chapter.

2.1 Requirements of the system

The purpose of the *Telecare Companion* system was to provide adaptive human interfaces for the telecare environment. The system was expected to form a network that would deliver primary care to the elderly, housebound, disabled or otherwise disadvantaged living in the community. This section gives an overview of the requirements of the system.

2.1.1 Users of the system

The telecare prototype system was designed to serve three types of user. The first group are the *primary users* who were the elderly, house-bound, disabled or otherwise disadvantaged. The system would run continuously on multimedia PCs in the users' homes. Each PC would run a stand-alone version of the *Telecare Companion* system, but would be able to contact any of the other users through the Internet.

Primary users are expected to be people who were previously isolated from the wider community due to a disability therefore the system should provide them with a means of communication in order to join and participate in a virtual neighbourhood, or community network. System requirements include the provision of facilities that enable users to communicate with each other using text, voice and video, and facilities that enable users to access information stored in local hypermedia networks or the Internet.

The second group of users are the care workers who would access the system in care centres or while visiting the primary users. The care workers would use the system to contact or be contacted by the primary users.

The third group of users are the doctors and professional health workers who will have a terminal in their surgeries in order to provide a remote consultation service for the primary users.

2.1.2 Communications requirements of the system

The system is required to provide the users with the ability to communicate using text, voice and images over the Internet.

The system should provide users with facilities to communicate using text. This includes three methods of communication:

- The facility to type, edit and print letter that can be sent by manual mail.
- The ability to connect to a mail server to send and receive e-mail.
- The facility to send text messages directly to other computers within *the Telecare Companion* network using TCP/IP.

The system also should provide users with the ability to communicate with other users of the system using speech or video using TCP/IP. The process of connecting to other computers on the network should be as simple as possible for example users need only indicate the person they wish to connect to and not have to enter IP numbers or other information.

Using the communication facilities users should be able to contact doctors for emergency calls or for remote consultation appointments. Similarly users should be able to contact care workers for help and advice, or have informal face-to-face conversations using text, voice and video with family, friends or previously unknown people who also share the network.

The system should encourage interaction between primary users and whoever is able to communicate with the network. This interaction would build a sense of a *virtual community* or *community network.*

2.1.3 Information requirements of the system

The system should be a source of information for the users for topics such as environment, health and local news. The information that can be accessed through the system should be updated regularly in order to encourage the users to interact with the system.

There is a range of information that primary users could access using the system, including general information, specific medical information and personal details. The general information includes material that is broadcast to all users and facts that the users request themselves. The broadcast information would include national and international news, local community network news and weather. The broadcast information would be downloaded to the users' computers from a central web site. The broadcast news and weather would be prepared and updated by the telecare service providers. Other general information that users would request themselves includes information relevant to their hobbies and interests, such as libraries of music, fiction/non-fiction, or photographs. Access should also be provided for browsing on the Internet.

Users also require access to specific information for their special medical needs. This information may be stored on the local machine or on a central server accessed through the Internet.

The users should be able to personalise the system by inputting information about themselves or family and friends, including multimedia files of images, sound and video clips. The system should perform the same function as a personal organiser, automatically prompting the user with reminders of appointments, birthdays and anniversaries.

2.1.4 Input and output

Interaction between the user and the system should be kept simple and users should be able to access the features with the minimum of effort. The number of steps required to operate the different features of the system should be kept to a minimum. Users should not have to re-dial, re-boot or enter passwords. All supporting applications should be running in the background and provide instant access to all services the users require.

Input into the system should not involve intensive use of the keyboard but should involve selection by the user of options using the mouse or by voice commands. Output by the system to the user should be clear and attractive using multimedia formats without being text intensive. The system should provide audio prompts and were appropriate the system provide a text-to-speech option to read out any text that is displayed. The presentation is to be imaginative, friendly and easily comprehended. Users who do not have experience with computers and those who are disadvantaged by age or handicap should be able to use the system intuitively.

2.2 Development of the prototype

A prototype was developed to conform to the requirements described in section 2.1 and to implement the usability principles described in chapter 1. This section describes the prototype that was built, highlighting the features that make the system easy-to-use and identifying the innovations that are unique to the prototype.

Prototyping was chosen as the development method because of the benefits to the system of incorporating feedback from the users into the development process. The design of the system is "user-centred" as it involves the users as much as possible. Carrying out early testing and evaluation with the users can validate the system by including functions that the users require and verifies that the system correctly performs the functions (Wagner, 1990; Durkin, 1994; Preece, 1994).

The prototype was developed to demonstrate the functions that would be performed in a completed system, indicating what options will be available to the users. Demonstrating the prototype at an early stage raises awareness of the system in the environment that it will be used and gains feedback from the target users. Demonstrations of *Telecare Companion* took place at BT Labs (the sponsors of the project) and at Open

Days at Bournemouth University. The feedback in turn influences the development of the features that are considered useful by the users and eliminates the time that would otherwise be wasted in developing features that would not be used.

The primary user would perform many activities with the system while care workers and doctors would use the system essentially to communicate with the primary user. Therefore the development of the prototype concentrated on the primary user interface. The professional user interface allows them to view and administer the underlying databases but other functionality has not been developed. A username and password is required to reach this interface.

There were four main phases of development of the prototype. The first phase involved the implementation of an easy-to-use interface. The second phase was the implementation of simple adaptable features that enabled the system to be personalised by the user. The third phase was the implementation of the adaptive features that affected the selection of information that suited the goals and knowledge of the user. The fourth phase involved the implementation of the adaptive features that affected the presentation of information that was suited to the cognitive style (CS) of users. This chapter concentrates on the first phase of development while the latter stages are described in the next chapter.

2.2.1 Technologies used in building the system

The prototype was developed on a multimedia PC operating under Windows connected to a Local Area Network, as shown in figure 8. The network connection provides the connection to email servers and access to remote Internet sites and remote computers.

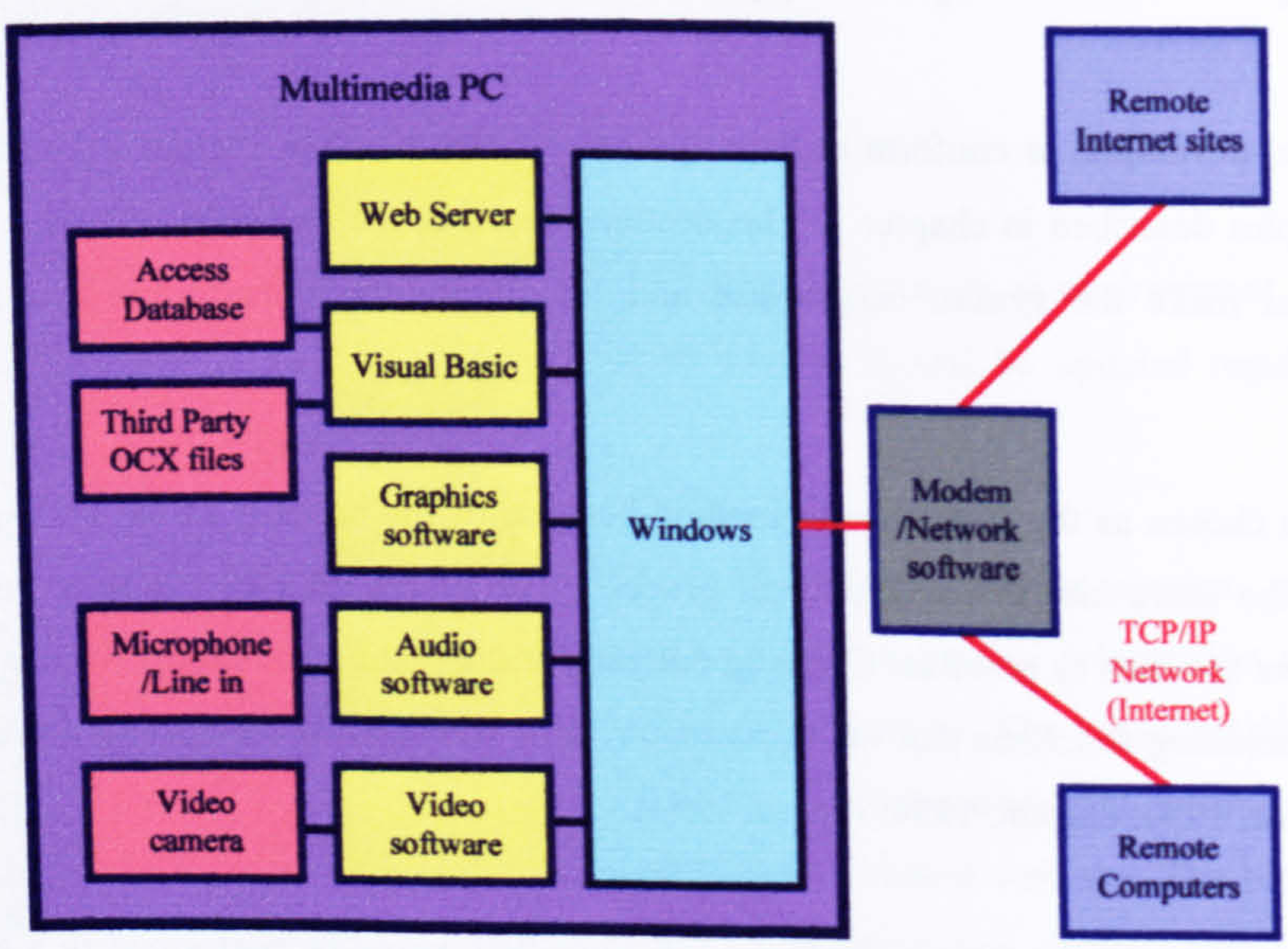


Figure 8: Development Environment of the prototype

Visual Basic (VB) was used as the main programming development language. VB allows the rapid development of the user interface, and is not limited, like multimedia authoring systems to the functionality of the built in controls. The functionality of the programming language was extended with the use of third party OCX files that allowed the application to communicate across the TCP/IP network.

Microsoft Access databases are used and manipulated by the VB program to store the information that is relevant for running the application. The type of information stored in the databases includes the material to be presented to the users (the knowledge domain), procedures the system follows in order to connect to remote computers (IP numbers, URLs, etc.), data users store about themselves or friends and the attributes of the user that the system stores in the user model (including the users preferences and system usage history).

Supporting software used in the development of prototype included the graphics, audio and video editing software that were used to create the media presented by the system.

2.2.2 System environment

This section describes the environment of the system that was implemented. First the structure of the system is described showing how the functionality of the system is divided into separate user options. Next the design of the interface is discussed, including the screen layout and how users can navigate through the system. Next the methods used to input and output information to and from the system and the users are described. Lastly the use of the *companion* character is discussed.

2.2.2.1 Structure of the telecare prototype

The structure of the system was kept simple and so there is no need to have a complex menu system. The design of the structure of the system followed the usability recommendations to group areas in a meaningful manner with a broad and shallow structure rather than narrow and deep (Helander, 1992; Shneiderman, 1998).

The required functionality was divided between seven main divisions in the prototype. The functionality of the options are discussed in more detail in sections 2.23 and 2.2.4.

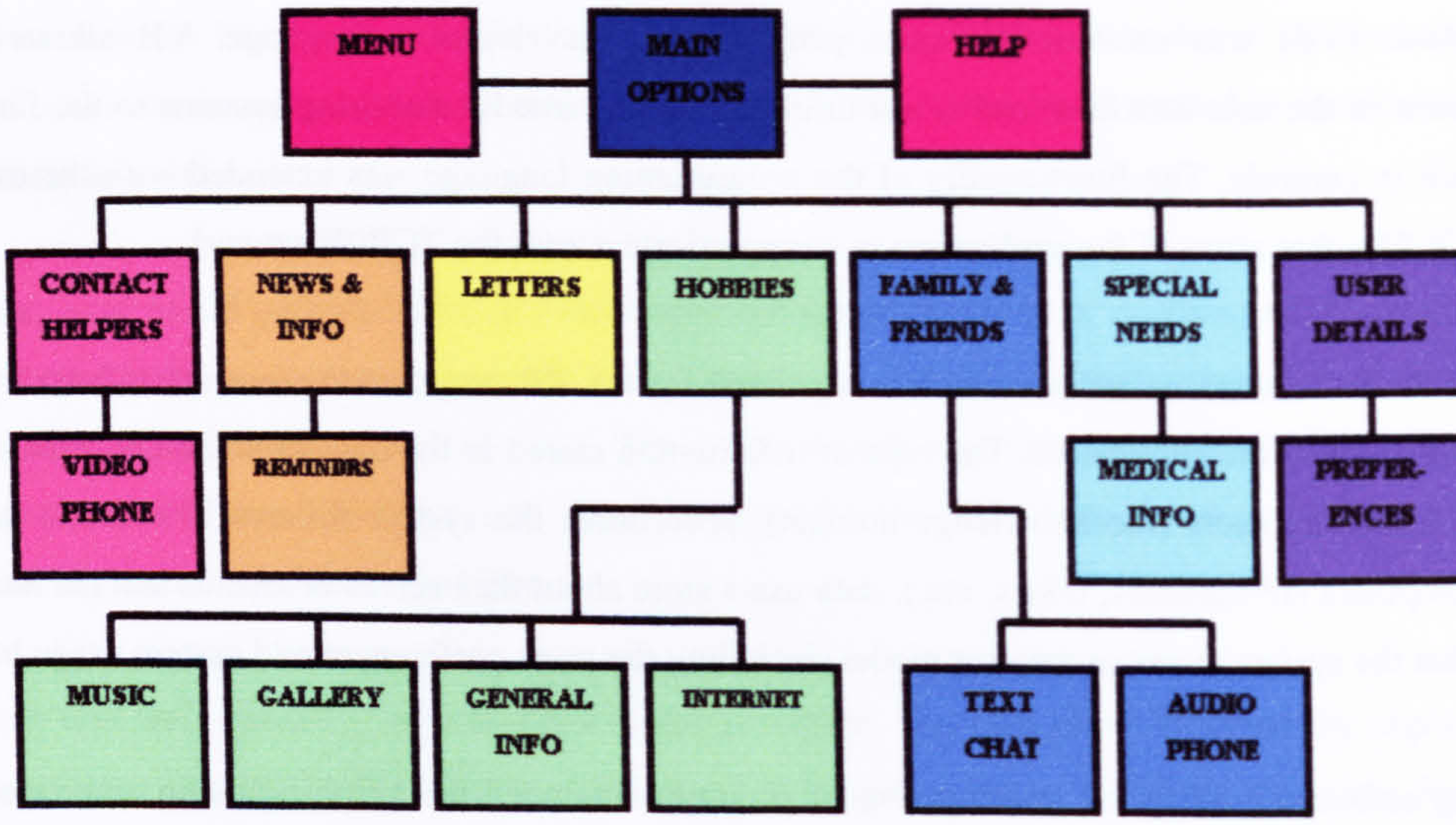


Figure 9: Structure of the prototype

Figure 9 shows how the required functionality is distributed throughout the prototype. There are seven main options that can be accessed through the *main option* screen. In addition to the seven options there are links to the *help* and *menu* screens. These two screens can also be reached from all other sections of the system. The *contact helpers* option enable users to make emergency or routine calls to doctors or care workers using the *videophone*. The *newscaster and information* option provides users with a video display for news broadcasts and also an interface for *reminders* of appointments and anniversaries. The *letters* option provides users with an interface to view, edit and send email. The *hobbies* option provides users with access to non-medical information stored within the system that may be of interest to the users including a collection of *music* files, a *gallery* of images, a library of fiction/non-fiction literature and an interface to the external *Internet*. The *family and friends* option provides users with an interface to a database in which they can store text, images or videos, including contact details of other people on the network. Users are able to select individuals and contact them using the *text chat*, the *audio phone* or the *videophone* interfaces. The *special needs* option provides users with an interface to edit their own *medical information*, and a gateway to access medical information on the Internet. The *user details* option provides users with an interface to edit their personal details, including their *medical details* and system *preferences*.

2.2.2.2 Interface design

The interface was designed to be uncluttered and simple to use. As primary users were not expected to be experienced with Windows programs it was decided not to confuse them by presenting a large number of windows that are open at the same time. Organising multiple windows places a greater cognitive load on users (Helander, 1988; Eberts, 1994; Shneiderman, 1998), therefore the interface consists of a single window that is maximised to cover the whole screen. There are no Windows style title bars or menus and the system has a distinct appearance using unique option buttons and information panels placed in fixed positions that appear to float over the top of the background images (figure 10). The choice of background image can be changed by the user or can be selected by the system automatically.

Figure 10 shows the effect of the background image with the main option buttons from the *Main Options* screen. The *Main Options* screen provides access to the seven main options of the system, and also the command buttons for *Help* and the *professional user* interface.

Figure 10: Main Option screen with professional user button visible

The command button for the *professional user* interface is normally kept hidden but is revealed when the mouse passes over the button. The command button is identified by the name "cmdProfessional" in the code and is hidden by the following line of code:

```
cmdProfessional.Visible = False
```

While the command button is hidden it cannot respond to mouse events so the button is placed on a blank image. When the mouse moves over the image the movement triggers a "MouseMove" sub procedure associated with the image. The following line of code is placed in the sub procedure that causes the professional user interface command button to appear:

```
cmdProfessional.Visible = True
```

The button remains visible for three seconds until the command button is hidden by a command triggered by a timer control.

The design and functionality of the option buttons are unique to the prototype. The buttons are large, clearly labelled, and contain an image that indicates the function of the option (as shown in figure 10). The appearance of the option buttons changes to indicate the different states causes by the user interaction using the mouse. Figure 11 illustrates the various states of the option buttons.

Figure 11: States of option buttons a. Normal b. Selected c. Clicked d. Dragged

The normal state of the option button is shown in figure 11a. The standard command button controls provided by VB could not provide all the required functionality therefore the option buttons were constructed using the VB Panel and Image controls. The 3D appearance was created by configuring the properties of the panel control, including the bevel that gives the appearance of the panel being raised, and the border width that dictates the apparent height. In the case of the *Contact Helpers* option button is identified as "panContact" in the code:

```
panContact.BevelOuter = 2
panContact.BorderWidth = 3
```

Figure 11b shows the effect of moving the mouse over the option button. To indicate that the button is selected the background colour is changed to scarlet by altering the "BackColor" property:

```
panContact.BackColor = SCARLET
```

At the same time the background colour of all other options buttons are changed to grey. After a timer indicates three seconds have passed the colour of the selected button is changed back to grey:

```
panContact.BackColor = GREY
```

The use of voice-overs and non-verbal auditory cues add valuable functionality to computer interfaces and aid the understanding of the user (Gaver, 1994; Bradey & Henderson, 1995). Therefore while the option button is selected a wave file plays either a spoken word or sound effect that indicates the purpose of the option.

Figure 11c shows the state of the option button when the mouse is clicked over the button. The outer bevel changes to give the effect of the button being inset. The effect is enhanced by slightly moving the image, which gives the appearance of the whole button being pressed:

```
panContact.BevelOuter = 1
imgContact.Left = imgContact.Left + MoveDown
imgContact.Top = imgContact.Top + MoveDown
```

When the mouse click is released the "MouseUp" sub procedure is triggered that changes the appearance of the option button back to normal. *MoveDown* is a variable that determines the number of pixels to move the image.

The user can obtain extra information about the main options by clicking on a button and then dragging and dropping onto the *Help* button. A video is then displayed which provides information about the selected option. During this operation the mouse is changed to a question mark (figure 11d).

The design of the *main option* screen (figure 10) was kept distinct from the design of the individual option screens. The option screens are designed using the same basic layout which follows the usability recommendation of maintaining consistency throughout the system (Tognaszzini, 1990; Dix, et al., 1993; Sheiderman, 1998). Figure 12 shows the design of an option screen, with a heading at the top, the main information space occupying the majority of the screen, user instructions along the bottom and command options along the right margin. The font size and colour were kept consistent within each area to emphasise the distinction between the different areas of the screen.

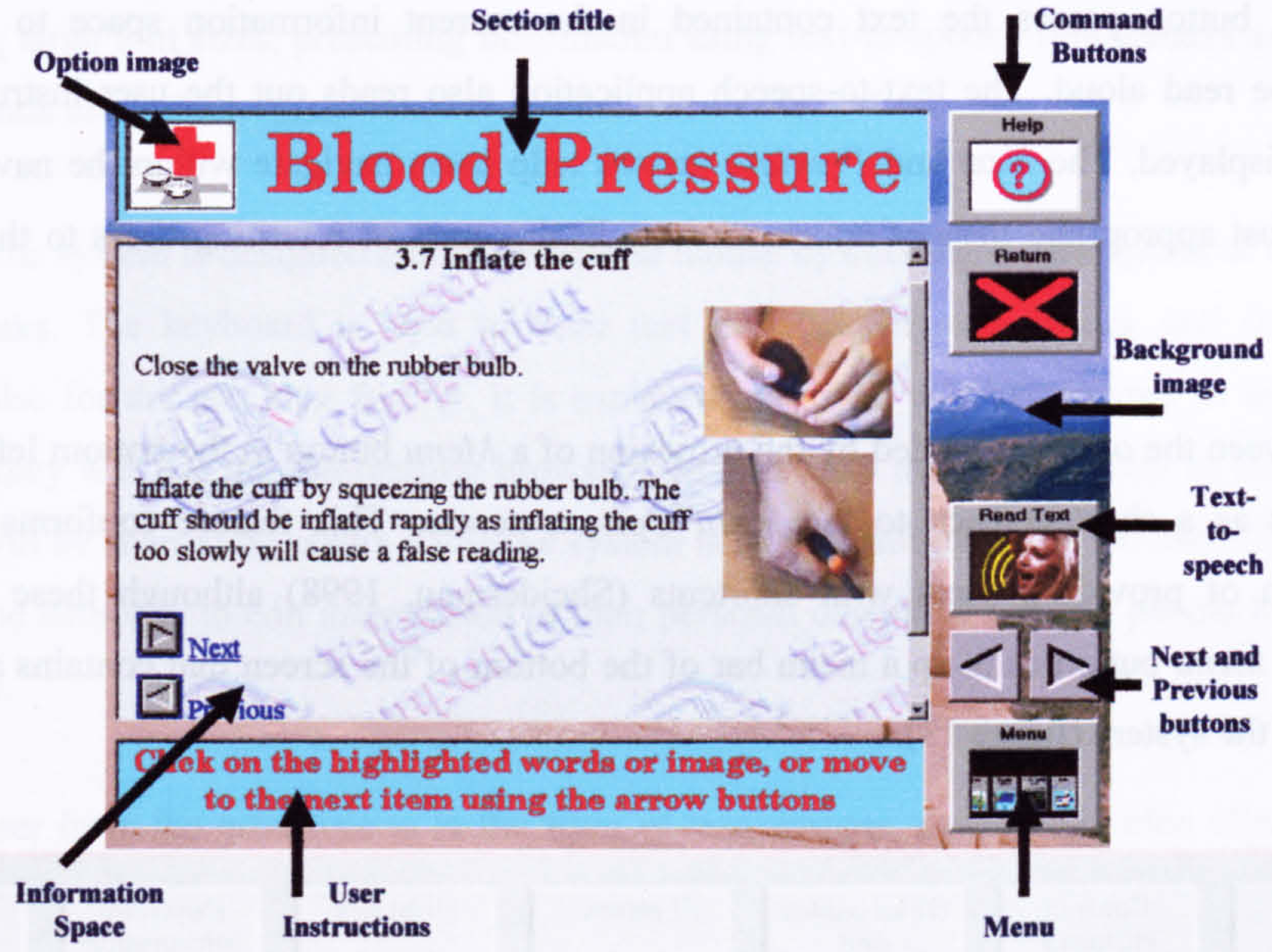


Figure 12: Option screen layout

The example in figure 11 is a screen shot from the Blood Pressure tutorial which is available within the *Special Needs* option and therefore the *Special Needs* image is placed in the title bar. In the above example the information space displays the contents of an HTML file which is part of the tutorial hypermedia network. The user instructions inform the user how to navigate through the information that is available in the current option.

The amount of information displayed on each screen is kept low, and there are few steps that users have to undertake to reach the main option screens. This conforms to the usability recommendation to reduce short term memory load (Shneiderman, 1998).

The command buttons within each option are a different shape from the option buttons on the main option screen. The command buttons have similar behaviour to the option buttons, but are smaller and are usually situated along the right hand side of the screen. The selection of command buttons that are available in each of the main option screens depends on the requirements of the options.

The *Help* button calls up a context-sensitive help screen. The system contains a large amount of information about the system that is organised into a hypermedia network. The point of entry into the hypermedia network depends on the location in the system from which the *Help* is requested.

The *Return* button presents the user with the previously viewed screen. The image placed in the *Return* button is usually the image that represents the previous viewed option which gives an indication of the screen that the user will be returned to. This feature confirms to the usability recommendation to permit an easy reversal of actions (Sheiderman, 1998).

The *Read Text* button passes the text contained in the current information space to a text-to-speech application to be read aloud. The text-to-speech application also reads out the user instructions when the screen is first displayed. The *Next* and *Previous* arrows help users navigate within the navigation space by selecting the most appropriate *item of information* to display next or returning users to the last previously viewed item.

Navigation between the options is aided by the provision of a *Menu* button in the bottom left corner of every screen that acts as a shortcut back to the *Main Options* screen. This feature conforms to the usability recommendation of providing users with shortcuts (Sheiderman, 1998) although these are pre-defined. Clicking on the *Menu* button calls up a menu bar of the bottom of the screen that contains a selection of the main options of the system (figure 13).

Figure 13: Menu Bar

When the menu bar is first loaded the top of the bar is placed at the bottom of the screen with a height of one pixel:

```
frmMenu.Top = 9135
frmMenu.Height = 1
```

A sub procedure associated with a VB Timer control has been programmed to quickly increase the height and move the bar up to give the appearance of the menu bar siding up from the bottom of the screen:

```
frmMenu.Top = frmMenu.Top - 100
frmMenu.Height = frmMenu.Height + 100
```

The effect is enhanced by the use of the sound effect of a gong being struck. By the time the gong has finished ringing the menu bar has stopped moving, covering the bottom third of the screen. The menu bar displays seven options including an option to return *Home* to the *Main Options* screen, *Help* and selection of five of the main options.

2.2.2.3 Input and output

The prototype conformed to the usability recommendations that features should be provided to help users with disabilities such as low vision, colour blindness, or have motor problems and cannot accurately use a mouse or keyboard (Christiansen et al., 1987; Tobias, 1987; Helander, 1988; Edwards, 1995; Shneiderman, 1998). A number of features were implemented such as reducing the amount of information that was displayed, using large font sizes, presenting information using text-to-speech synthesisers and allowing users to input commands using their voice.

User input into the system is designed mainly to use the mouse by clicking on the option or command buttons and on hyperlinks. The keyboard is used to enter text into the personal details, and family and friends databases and also for the text chat facility. It is expected that users will be required to enter text on fewer occasions than they will use the information browsing facilities and that the majority of text that is required by the system will be entered by others while the system is being configured for the user. The user, however, will still have the authority to edit information in their personal databases and add people to their family and friends database.

Output to the user from the prototype is in the form of text, images, sound and video clips. Text-to-speech features allow the user to hear the text that is displayed in the information space. Text-to-speech synthesisers receive words in textual form, convert the words to phonemes (sound elements) and output the sound of the phonemes using appropriate pitch and duration. The quality of synthesised voice is often far inferior to recorded voice and pronunciation is not always accurate, but text-to-speech has a number of advantages over recorded voice including the a relatively small application size and the system is not limited to the number of words that have been pre-recorded (Helander, 1988; Mountford & Gaver, 1990; Dix, et al., 1993; Blenkhorn, 1995).

A number of different text-to-speech software packages were used in the development of the system including Creative Labs *TextAssist*, BT Labs *Laureate* and Microsoft *Voice Text*. The Creative Labs *TextAssist* application enables text-to-speech using a synthetic voice. The application works out the phonetic pronunciations of the words and simulates the sounds. Aspects of the voice including the rate and pitch can be altered dynamically by embedding control characters within the text that is being read, for example the characters "[:nb]" and "[:np]" would switch between two types of voice (Creative Labs, 1995a). The *TextAssist* application is controlled within the *Telecare Companion* application by the use of an intermediate application to serve as an interface between the two applications called "tassdde.exe" (the *TextAssist* dynamic data exchange application).

The *TextAssist* dynamic data exchange application is started within *Telecare Companion* using the VB Shell command:

```
RetVal = Shell("TASSDDE.EXE", 1)
```

A VB Text Box control that is hidden from the user (named "txtSpeech" in the code) is used to contain the text and any control characters to be converted to speech. Properties of the Text Box are set up to link with the *TextAssist* dynamic data exchange application. The aspect of the control being linked is defined as the contents of the Text Box:

```
txtSpeech.linkItem = "txtSpeech.text"
```

The application that the text is being linked to is defined as *TASSDDE* application and the function of the *TextAssist* dynamic data exchange application that is being invoked is the *TALK* function:

```
txtSpeech.linkTopic = "TASSDDE|TALK"
```

When the user selects the *Read Text* option the application transfers the contents of the Text Box to the *TextAssist* dynamic data exchange application using the *Linkpoke* method:

```
txtSpeech.LinkPoke
```

The main problem with *TextAssist* is that it sounds like a computer-generated voice that does not contain any emotion and was regarded as unnatural by many of the people who witnessed the prototype being demonstrated. Therefore other text-to-speech applications were examined. BT Labs *Laureate* constructs words by concatenating samples of recorded voice and produces a relatively natural sounding voice (Page & Breen, 1996). *Laureate* was used to record the soundtrack for the video and the recorded sound clips that accompany *the Companion* but it was not possible to embed the *Laureate* functions dynamically within the application.

Another text-to-speech application used was the Microsoft *Voice Text* (Microsoft, 1997) which was similar to the *Laureate* system but could be controlled dynamically by the *Telecare Companion* program. *Voice Text* is the high level interface to the Microsoft text-to-speech application, in this case between the *Telecare Companion* application and the Microsoft Text-to-speech application.

First an object is created to act as the interface between *Telecare Companion* and the Microsoft text-to-speech application that can be accessed throughout the whole program:

```
Global VTxt As Object
```

The object is assigned to reference the Microsoft *Voice Text* application:

```
Set VTxt = CreateObject("Speech.VoiceText")
```

For the Microsoft text-to-speech application to be invoked the *Telecare Companion* application has to be registered within the Microsoft *Voice Text* application:

```
Call VTxt.Register("", "Telecare Companion")
```

The *Telecare Companion* application can then manipulate the *Voice Text* object from within the application specifying attributes such as the rate in which words are spoken:

```
VTxt.Speed = 150 ' default speed
```

For text to be spoken by the *Voice Text* application the text has to be sent to the *Voice Text* object and the *Speak* function invoked:

```
Call VTxt.Speak(txtSpeech.Text, &H1 Or &H200)
```

The prototype enabled the users to issue some voice commands that the system would respond to. Voice controlled devices have had a reputation of unreliability and complexity in the past but are growing increasingly sophisticated (Shaw et al., 1995). A number of voice recognition packages have been made commercially available for PCs such as Dragon Naturally Speaking, Microsoft's Voice engine, and IBM's ViaVoice. Some voice recognition packages are designed mainly for dictation while others can be used to control other programs. In the telecare prototype the Creative Labs *VoiceAssist* program was used to provide an interface for the voice commands (Creative Labs, 1995). *VoiceAssist* is a separate application that can respond to a number of voice commands to control different applications. Each command is set up by the user defining a name, speaking the command and defining the action that is to be performed when the command is detected. Each user has to train the system by speaking the command into the computer's microphone a number of times. The system uses these sample voice patterns to compare with any sound it detects while the system is running. The action is a predefined sequence of key presses or mouse clicks that the user specifies should be performed when the command is detected (referred to as a *macro*). Figure 14 illustrates the operation of a voice command.

1. The start screen (which is within the blood pressure tutorial).
2. The user speaks the voice command "Help" into the computer's microphone.
3. The *VoiceAssist* program recognises the word "Help" and performs the *macro* associated with the word, which in this case is to perform a mouse click in the top right hand of the screen on the *Help* command button.
4. The final screen, the *Help* interface, is displayed.

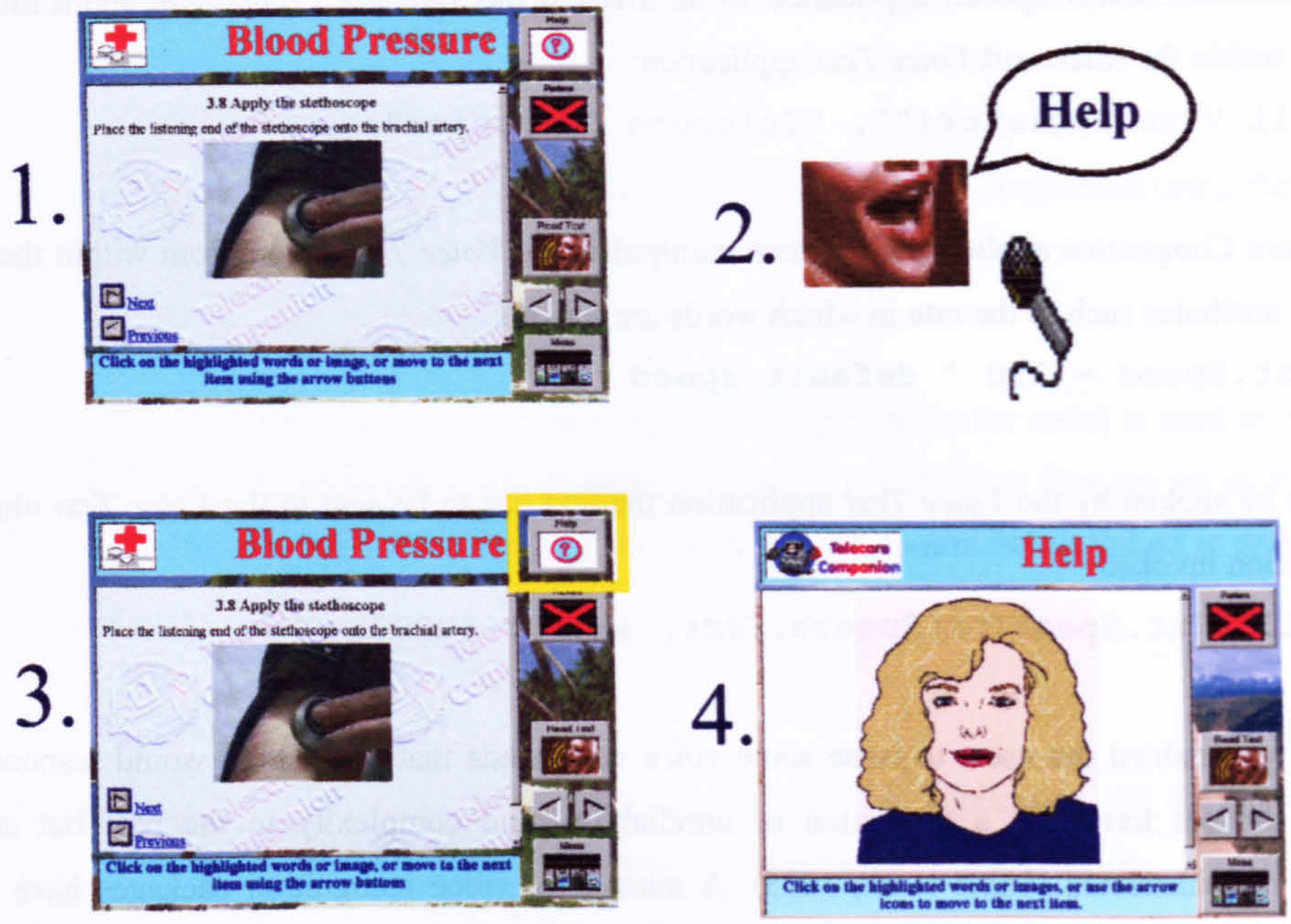


Figure 14: Voice Commands

One problem of using the *VoiceAssist* application is that it can not be used at the same time that another sound is being played. It remains a separate application and displays a floating bar window (figure 15) that remains on view at all times. The bar gives feedback to the user by showing the level of audio received (to the left of the bar) and indicates whether a command was recognised.

Figure 15: VoiceAssist floating bar

The VoiceAssist application is used to demonstrate voice commands, however a professional telecare application requires an integrated voice command system that does not use extra windows, would not need to be trained by the user and would not interfere with the audio output of the system.

2.2.2.4 The Companion

To encourage the non-expert computer users to use the system it is given a human face, or *personality* to act as a companion accompanying them through the system. This is represented in the prototype by an animation of a clip-art face that appears at various times to give information to the user. The voice of *the companion* remains consistent throughout the system and is provided by *Laureate* the BT Labs text-to-speech software. It is anticipated that a finished version of the prototype system would feature video footage of a well-known television presenter or newsreader.

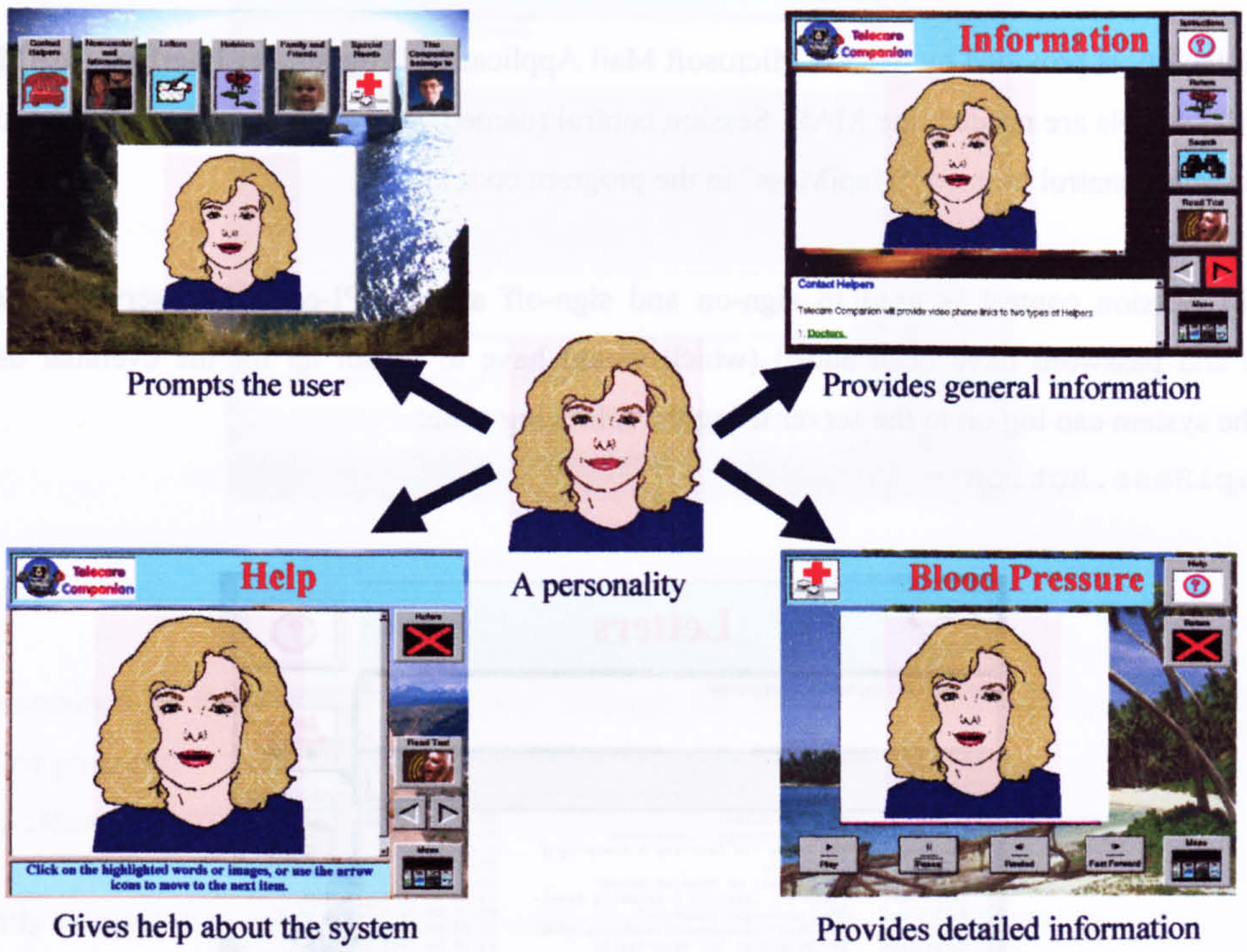


Figure 16: The Companion

As illustrated in figure 16 *the companion* is used throughout the system in a number of situations, to prompt the user (indicating when a news bulletin is due to be broadcast), providing general information (featured in video clips contained in the general hobbies information option), giving help about the system (featured in video clips contained in the help system), and providing detailed information (featured in video clips contained in the *Special Needs* information). This feature was used to conform to the usability recommendation of offering informative feedback (Shneiderman, 1998).

The use of the *companion* is unique to the telecare prototype although the use of personalities to provide help and tips to the user has been incorporated into commercial software such as the *Office Assistant* in the Microsoft Office suite of programs.

2.2.3 Communication features of the system

One of the requirements of the system was that users should be able to communicate asynchronously using email, and synchronously using text, audio and video.

2.2.3.1 Email

The email facility is provided by the VB Microsoft Mail Application Programmer Interface (MAPI) controls. Two MAPI controls are needed, the MAPI Session control (named "MapiSess" in the program code) and the MAPI Messages control (named "MapiMess" in the program code).

The MAPI Session control is used to sign-on and sign-off any MAPI-compliant server. When a valid username and password have been added (which would have to be set up for the eventual users of the system) the system can log on to the server using the following code:

```
MapiSess.Action = 1
```

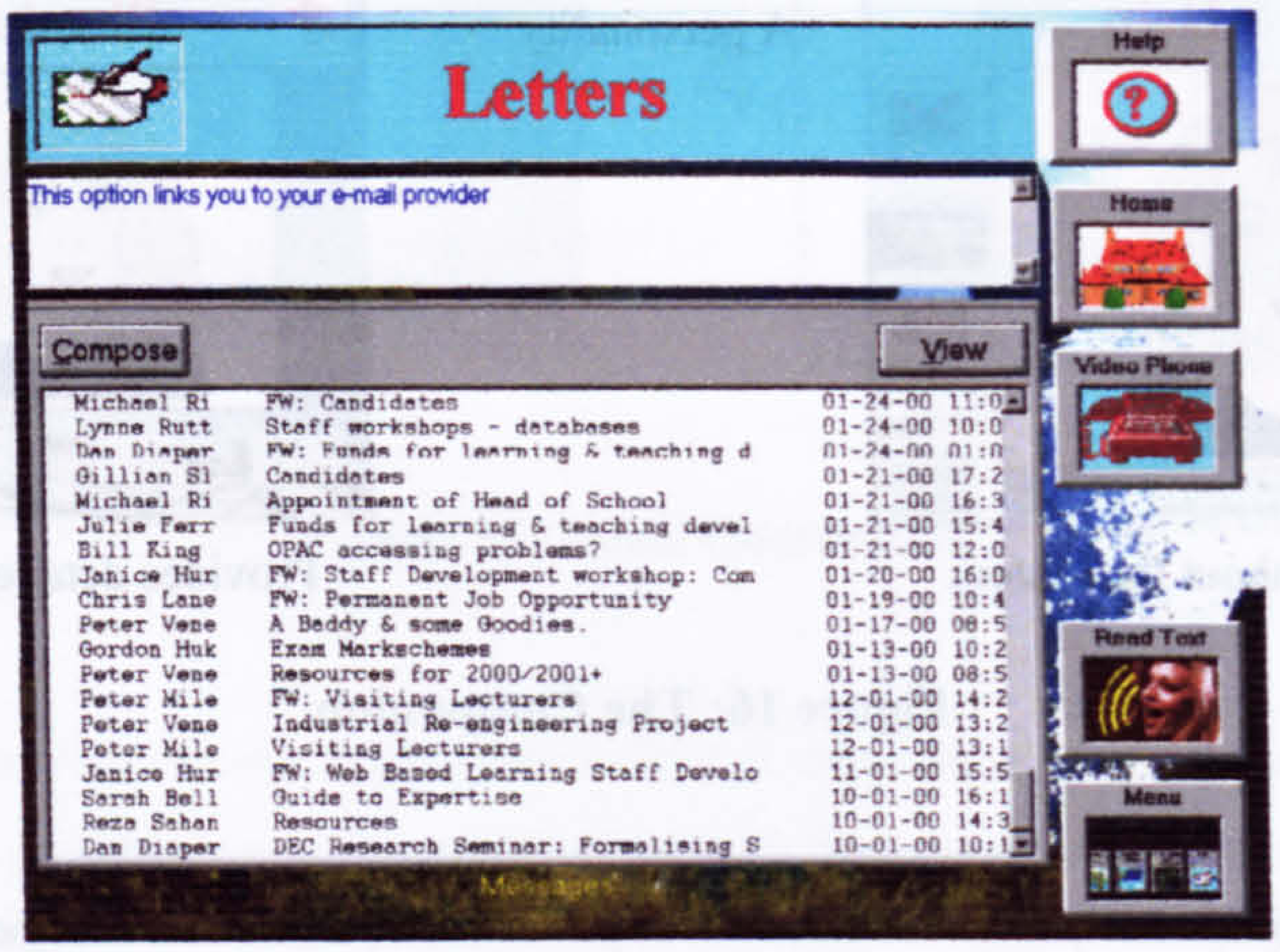


Figure 17: Email browser interface

The MAPI Messages control is used to list, read, delete, create and send messages. The messages are listed in a VB List Box control (figure 17) by stepping through each message accessed by the MAPI Messages control and extracting the senders' name, the subject heading and the date the email was received using the following MAPI Messages control methods:

```
MapiMess.MsgOrigDisplayName
MapiMess.MsgSubject
MapiMess.MsgDateReceived
```

When a message is selected from the list *Telecare Companion* displays the message in the space where the list was displayed (figure 18). Messages can be stepped through using the *Next* and *Previous* arrows above the message. The current message that is being examined at any time is identified using the *MsgIndex* property:

```
MapiMess.MsgIndex
```

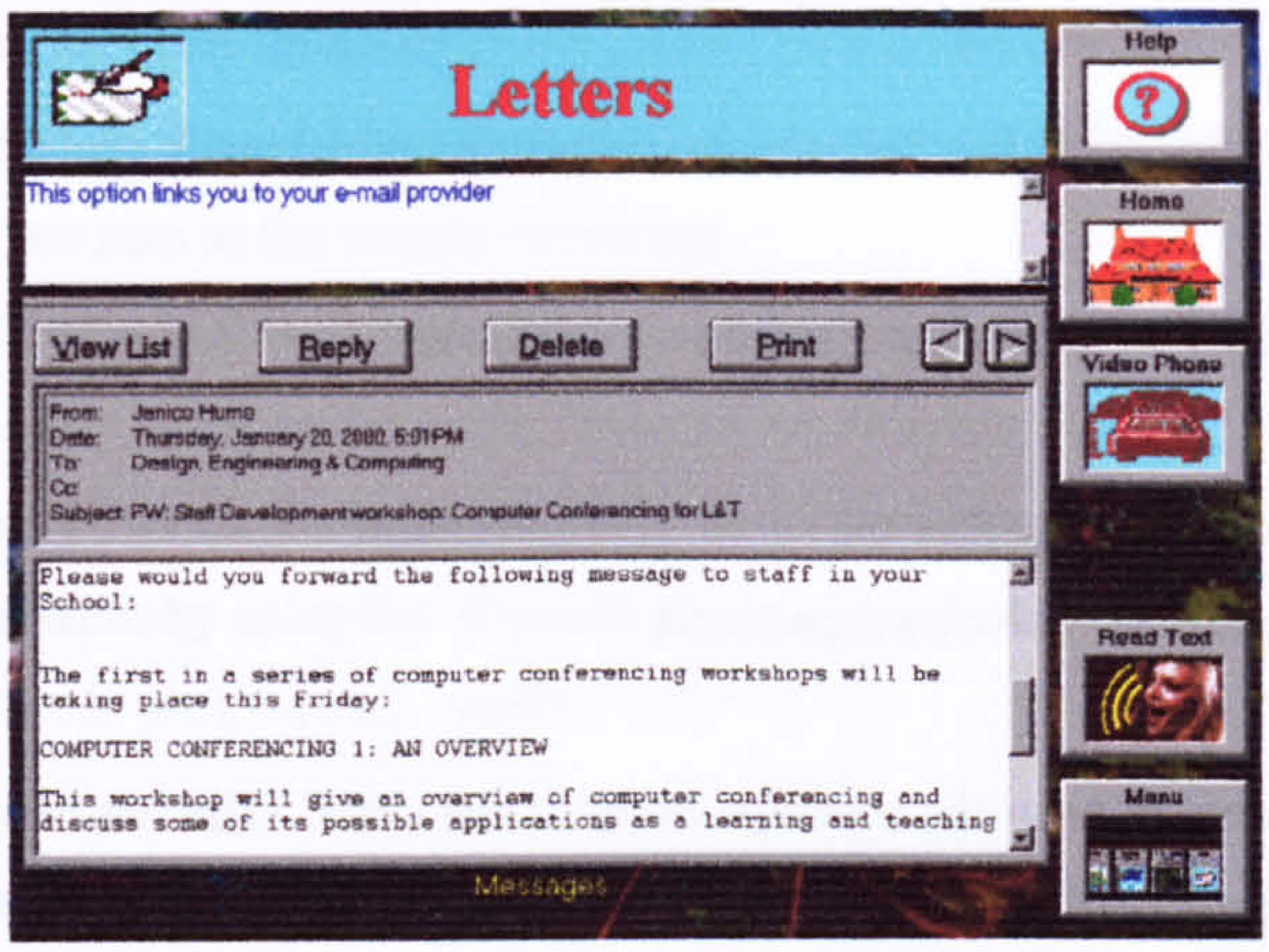


Figure 18: Interface to read email messages

The text contained in the body of the current message (as shown in figure 18) is accessed using the *MsgNoteText* property:

```
MapiMess.MsgNoteText
```

The currently selected message can be deleted using the following code:

```
MapiMess.MsgIndex = lstMailList.ListIndex
MapiMess.Action = vbMessageDelete
```

Users are able to reply to the currently selected message or compose new messages can be composed depending on the action property setting:

```
MapiMess.Action = MESSAGE_REPLY
MapiMess.Action = MESSAGE_COMPOSE
```

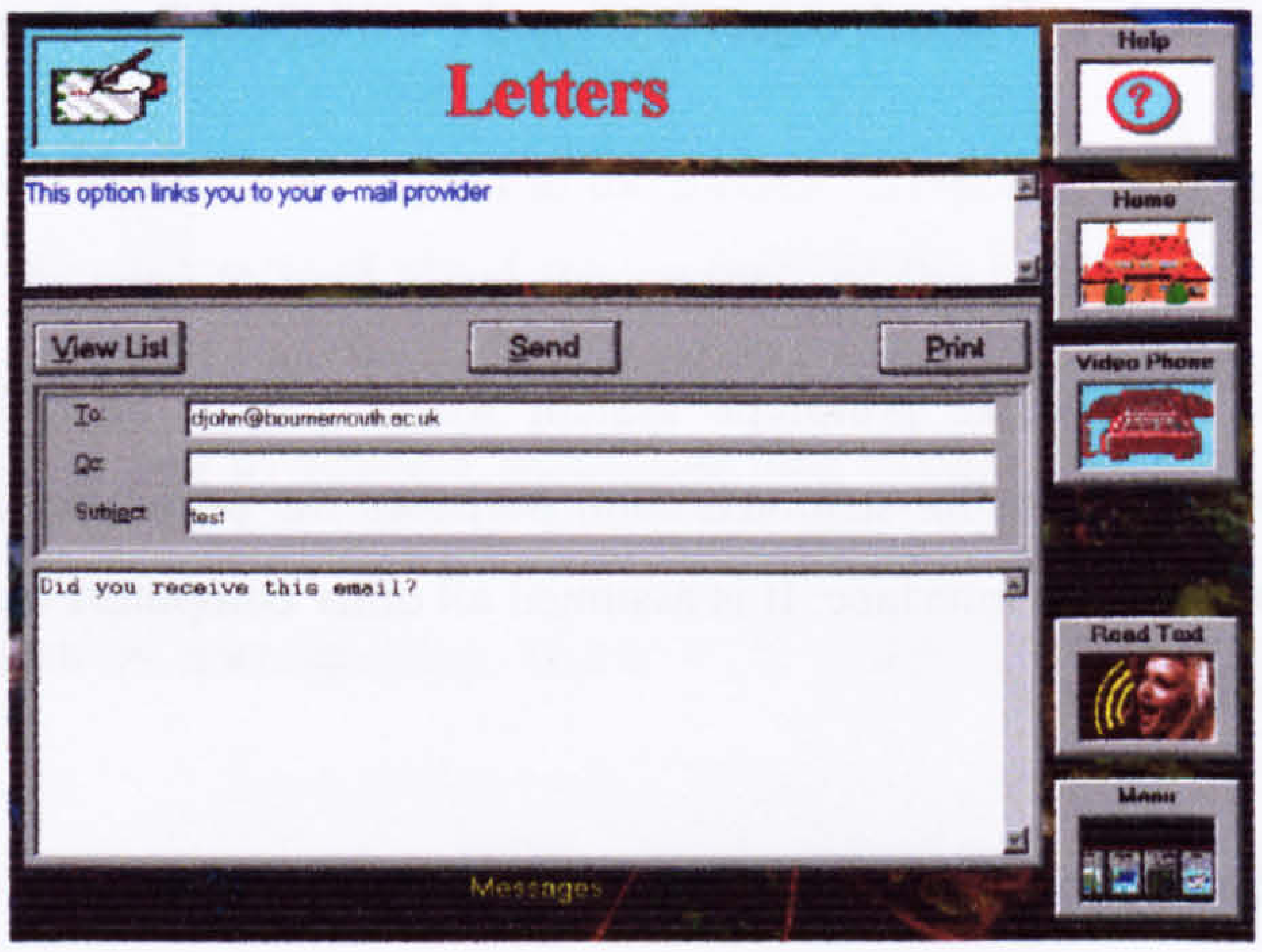


Figure 19: Email Interfaces to read and compose messages

Telecare Companion allows users to compose email messages and send them (figure 19). The subject and body text are extracted from the prototype by the MAPI Messages control:

```
MapiMess.MsgSubject = txtNewSubject
MapiMess.MsgNoteText = txtNewMessage
```

The recipient's address is verified before the message is sent by checking it against the list of registered users in the e-mail system:

```
MapiMess.Action = vbMessageResolveName
```

The MAPI Messages control then handles the sending of the email:

```
MapiMess.Action = vbMessageSend
```

The print option allows users to print the message body of the email. The hard copy could then be sent as a letter. Users of the system are also able to send messages to each other in real time using text, audio or video. Using the *Family and Friends* option in the *Telecare Companion* prototype users are able to select people to contact and be given a choice of whether to use text, audio or video.

2.2.3.2 Text chat

The Microsoft Winsock control is used to provide access to remote computers over the Internet. The Transfer Control Protocol (TCP) allows connections to remote computers to be created and maintained and allows data to be streamed between the computers. In order to contact a remote computer the IP number of the computer is needed. In the development of the prototype it was assumed that all IP numbers of computers that will be accessed by the primary user are known and will be entered in a database by a professional user. All the primary user will need to do is select the desired person in their *Family and Friends* database and the system will make the connection.

The Microsoft Winsock control is used as the interface between the application and the TCP/IP network for the *Text Chat* option. In the code a Winsock object is created ("oWinSock") and set to listen for a connection request:

```
oWinSock.Listen
```

A commercial version of the telecare prototype system would always be in listening mode when not connected to a remote computer, but for demonstration purposes the prototype uses the listen option only when displaying the communication interface. It is assumed all other computers on the network will be set to listening mode as the default mode.

When making a connection request the IP number of the computer that is to be contacted is passed to the "Connect" method of the Winsock control:

```
oWinSock.Connect (currentIP)
```

When a connection request is detected the Winsock sub procedure *ConnectionRequest* is triggered. Provided that there are no errors it is automatically accepted by *Telecare Companion*:

```
oWinSock.Accept requestID
```

Once connected both computers can send and receive data. Text is typed into the Text Box at the bottom of the screen (figure 20) and when the send button is clicked the contents of the text box (plus end-of-line and carriage return characters) are sent to the remote computer:

```
oWinSock.SendData (txtInput.Text & Chr(13) & Chr(10))
```

When data is received the Winsock *DataArrival* sub procedure is triggered. The data is retrieved by the *Telecare Companion* application by using the Winsock *GetData* method:

```
oWinSock.GetData strData, vbString
```

The received data is placed in the string labelled "strData" which can then be manipulated within the application: in this case the text is displayed in the large chat window (figure 20). Text sent from the local machine is also displayed in the chat window following the ">" symbol.

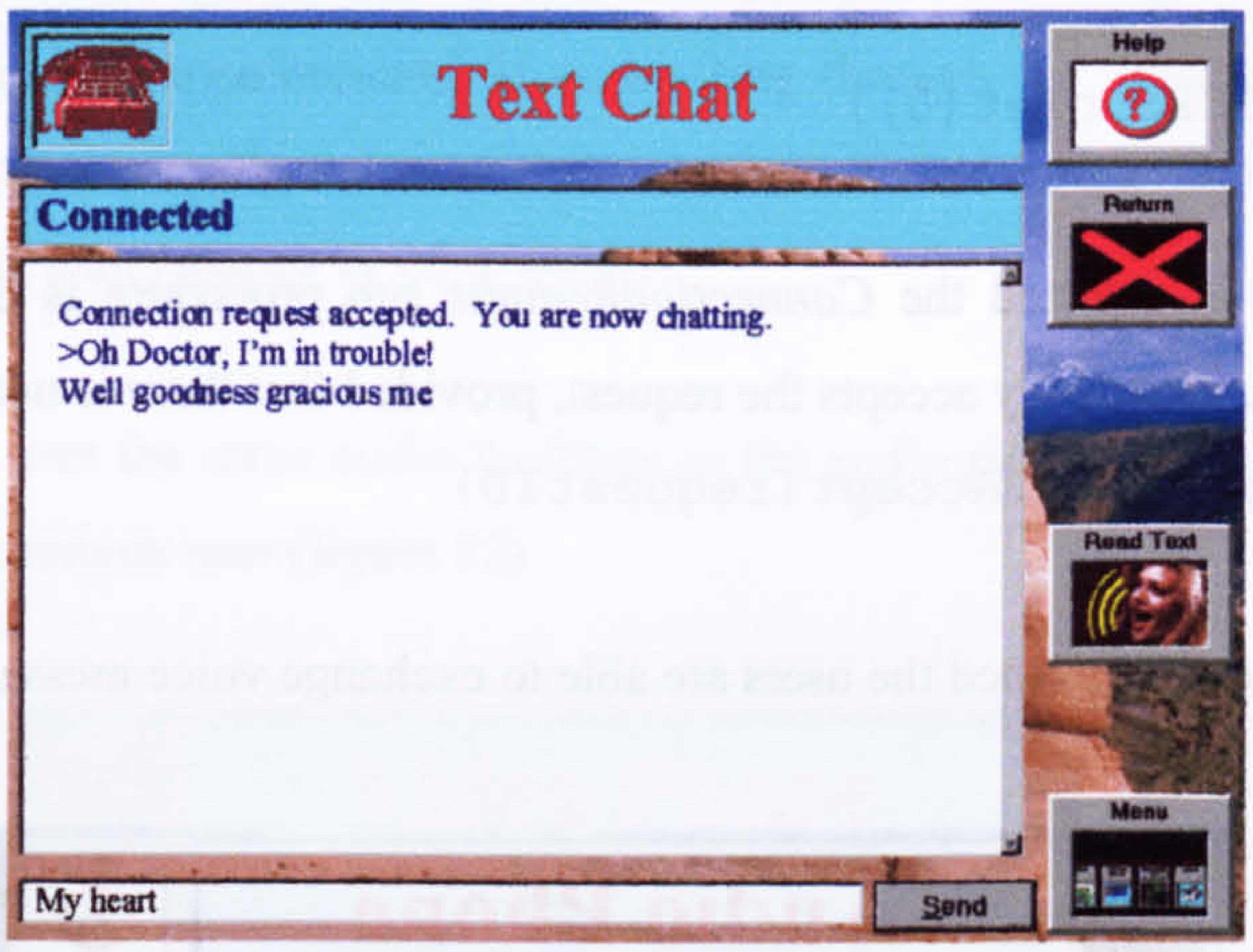


Figure 20: Text chat interface

The contents of the chat window are also copied to the hidden "txtSpeech" text box and the *TextAssist* text-to-speech application can be used to read aloud the contents of the "txtSpeech" text box. Embedding the control characters in the text sent to the *TextAssist* application changes the voices used to read the text. A different voice is used for text sent to different computers. The "[:nb]" characters specifies the voice to use for the local machine:

```
txtSpeech.Text = txtSpeech.Text + " [:nb] " + txtInput.Text
```

As data arrives from the remote computer it is also added to the "txtSpeech" Text Box after the "[:np]" characters that specifies a different voice to use for text from the remote machine:

```
txtSpeech.Text = txtSpeech.Text + " [:np] " + strData
```

When the *Read Text* command button is clicked the contents of the "txtSpeech" Text Box are read aloud by the *TextAssist* text-to-speech application using different voices for different people in the conversation. The session is closed when one of the participants exits by clicking on the return button.

2.2.3.3 Audio phone

The telecare prototype provides a facility for users to send voice messages to each other in real time. The audio phone is enabled using the NetManage Winsock control, which uses a library of functions in the Wavedll.dll application that permits wave streaming over the Internet. First the Wavedll.dll application is registered from within the *Telecare Companion* application using the VB Shell command:

```
rc = Shell("REGSVR32 /S WAVEDLL.DLL", 1)
```

It is then possible to create a wave stream object:

```
Set wStream = CreateObject("WaveStreaming.WaveStream")
```

The NetManage TCP control works in a similar way to the Microsoft Winsock control while listening for a connection request:

```
Call Listen(TCPSocket(0))
```

When a connect request is detected the *ConnectionRequest* sub procedure is triggered and the *Telecare Companion* application automatically accepts the request, provided that there is not an error:

```
Call TCPSocket(Idx).Accept(requestID)
```

Once a connection has been established the users are able to exchange voice messages.

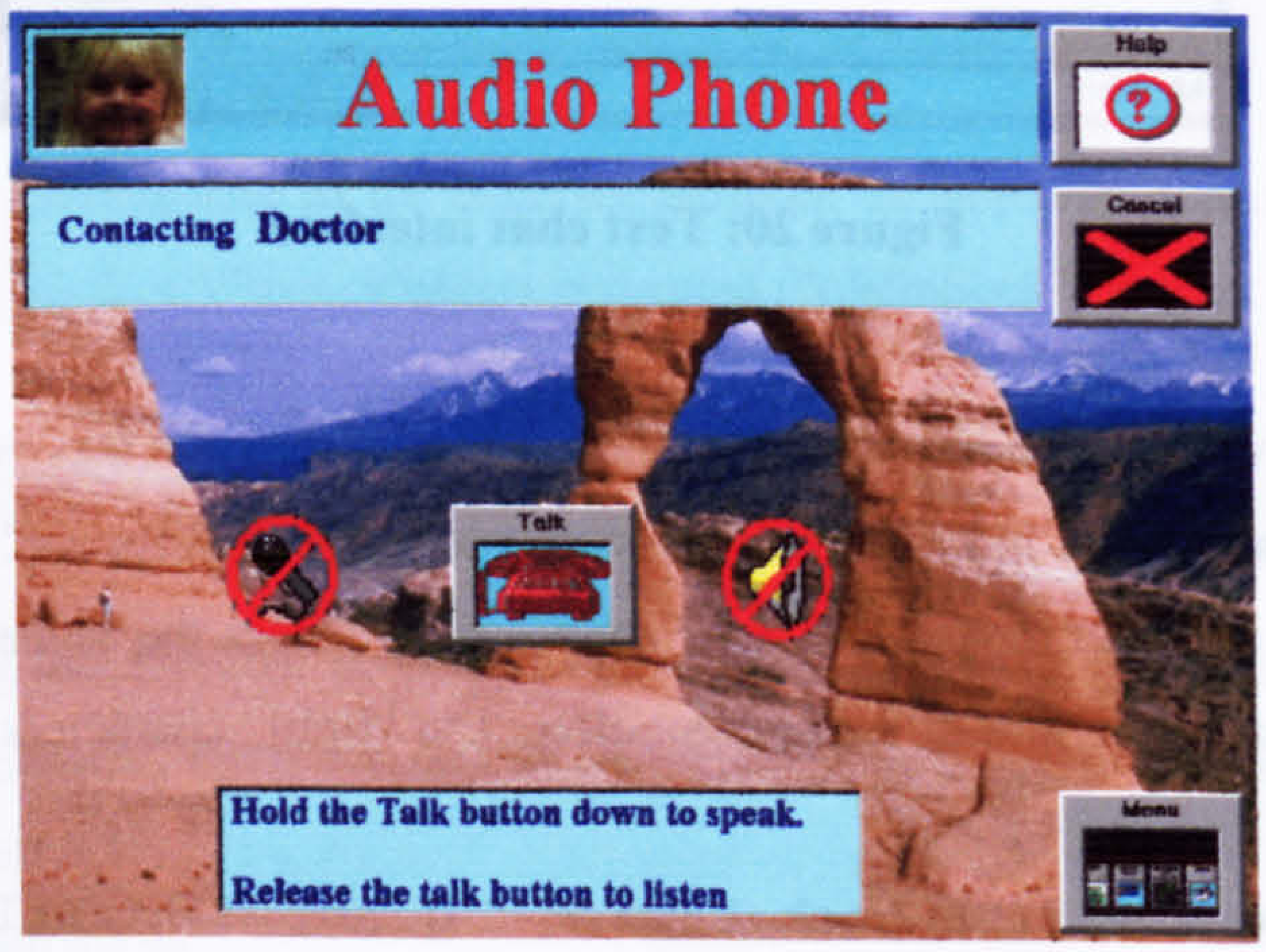


Figure 21: Audiophone interface

In order to send audio to the remote computer the user has to click on the *Talk* button (figure 21) and hold it down while they speak their audio message. A variable (named "iport" in the code) is assigned to hold the audio stream:

```
iPort = wStream.StreamInQueue
```

While there is data to playback the wave stream object streams the data across the network:

```
rc = wStream.PlayWave(Me.hWnd, iPort)
```

When data arrives from the remote computer the NetManage Winsock control triggers the *DataArrival* sub procedure:

```
Call TCPSocket(Index).GetData(WaveData, vbByte+vbArray, .wavechunksize)
```

The data that is received is saved in a buffer and queued for playback:

```
Call .SaveStreamBuffer(Index, WaveData)
Call .AddStreamToQueue(Index)
```

2.2.3.4 Videophone

A videophone facility was provided using a configuration that was unique to the telecare prototype. The videophone can be accessed through the *Family and Friends* option or through the *Contact Helpers* option for emergency calls or routine appointments. If connecting through the *Family and Friends* option the videophone will contact the currently selected person, while if connecting through the *Contact Helpers* option the user has to select either *doctor* or *care worker*.

The videophone interface uses the same audio facilities as the audio phone, but has the added dimension of displaying an image of the remote user (figure 22).

Figure 22: Videophone interface

The video image quality of applications that allow video conferencing over the Internet including *NetMeeting* and *CUSeeMe* were reviewed. Because of the limited bandwidth of the Internet pictures are not always smooth and are often not updated for several seconds. Where images are smooth they are not in-synch with the voice. Therefore it was decided not to attempt smooth video streaming but to send a still image every three seconds.

For demonstration purposes a camera was attached to each PC using the *LogiTech QuickCam* application running as a separate standalone application in the background, saving and updating an image on the local computer every two seconds. The Microsoft Personal Web Server application was used to share the saved images over the Internet. The local computer uses a *NetManage* HTML control that requests the image of the remote computer user over the Internet using the HTML control function *RequestDoc* sending the URL of the image saved on the remote computer.

```
HTML1.RequestDoc frmDatabaseContacts.txtFields(5)
```

The URL of the remote user is stored in a database as part of the contact details of that person. The retrieved image is displayed in the HTML control window (figure 22). A timer is set to trigger a procedure that requests the image every three seconds.

Using a web server running on the local machine would not be practical in the home as the *QuickCam* application would be continually running and the user's image would always be available on the Internet for anyone who knew the URL. A more secure method would be to send the image only to the computer to which the local is connected using the Winsock control.

2.2.4 Information features of the system

The provision of information requirements of the system included information that was presented to the users and information that was stored by users. Information that was presented to users includes broadcast information that would be updated remotely, information for *Hobbies* or *Special Needs* that might be stored locally or on the Internet. Information that was stored by the user' includes data that the user wants to store about themselves or family and friends.

2.2.4.1 Broadcast Information

Figure 23: The broadcast information interface

The Newscaster and Information option provides information that is broadcast to all users. This includes general news bulletins, local community network news and weather (figure 23). The prototype uses video files stored on the local computer, however it is anticipated that the information would be in the form of files downloaded from an Internet site that would be updated regularly by the administrators of the system.

2.2.4.2 Locally stored information

The information stored on the local machine for hobbies, special needs and help information about the system itself was organised as a hypermedia network. The prototype contains demonstration information including a collection of midi files, a gallery of images and a library of history and literature files. The hypermedia network is made up of nodes and links; the nodes are the information units (*items of information*), and the links are the relations that connect the nodes. The nodes may contain material in any multimedia format including text, graphics, audio, animation or video clips. The links are embedded within the text files and supporting databases.

A hierarchical organisational structure was provided to help users overcome the problems of disorientation and distraction that may occur while browsing through the information unguided. The information is organised into a hierarchy of subjects sub-divided into topics that are in turn sub-divided into the sub-topics that contain the individual *items of information*. To reduce the cognitive overhead of the user a hypermedia browser was developed that required only minimal cognitive effort, and provided navigational tools such as contents and indexes, search query mechanisms, and a facility to go back to previously viewed nodes (figure 24).

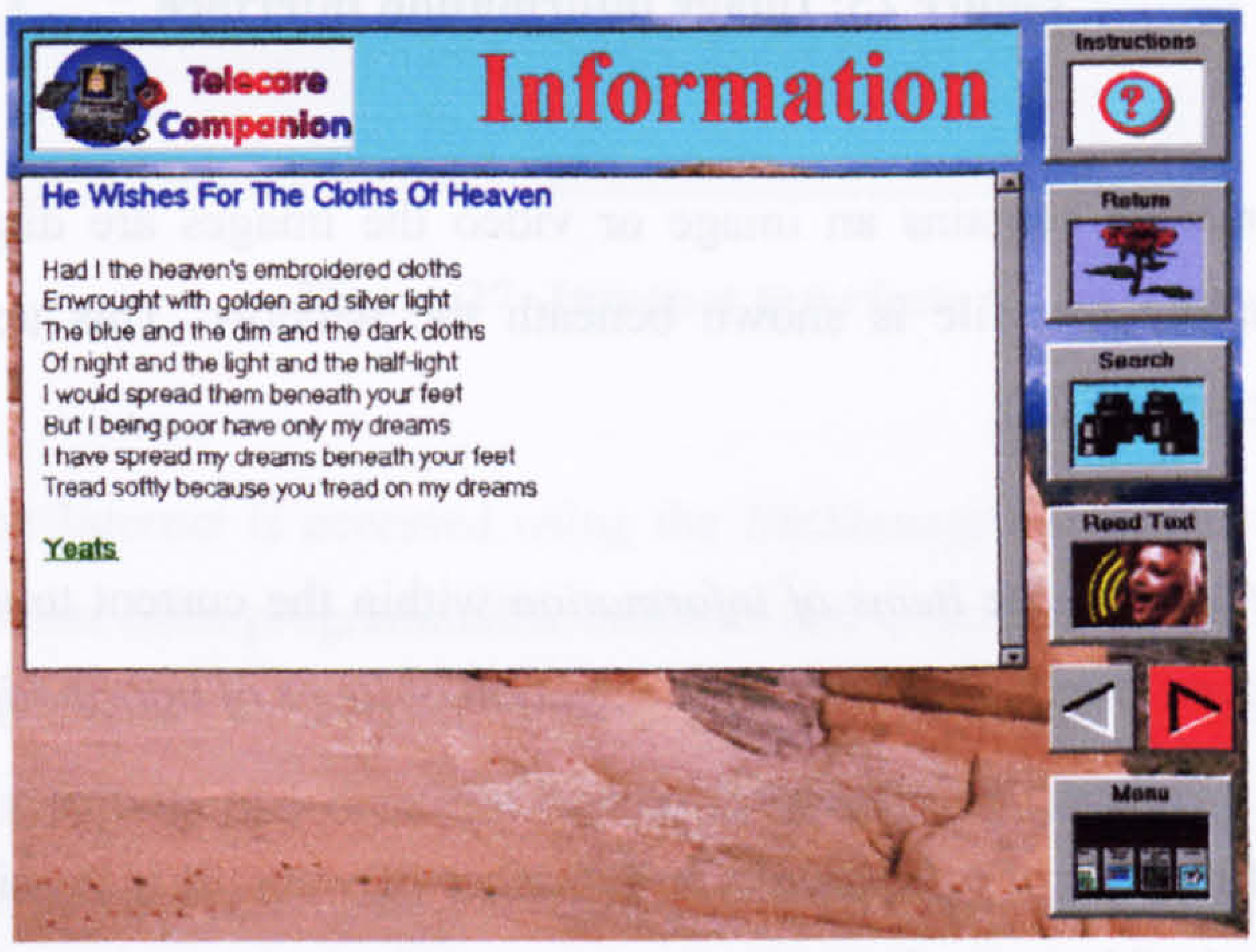


Figure 24: Text Information interface

The original design of the hypermedia browser interface was based on a hypertext example in *Visual Basic Multimedia Adventure Set* (Jarol, 1994) but was modified and extended to include other media and include the required navigational features. In order to allow users to click on hyperlinks embedded in the text files the text is displayed using a VB Picture Box control that allows headings and links to be displayed in different coloured text (figure 19) and can detect mouse events (unlike the VB Text or Label controls).

The text files are first prepared for displaying in the picture box. The text files contain special characters for the title ("###") and links are contained between "##" and "|" characters. The destination of the link is contained between the "|" and "~" characters:

```
##Far From The Madding Crowd|Crowd.txt~
```

The system strips away the special characters and builds lines of text in an array of characters not exceeding the maximum line width. A record is kept of the location of each link. The text is printed directly onto the picture box. Headings are printed in blue in a larger font size, normal text is printed in black while links are printed in green and are underlined (figure 24 and 25). Users can scroll down the text by clicking on the VB Scroll Bar control. The application then calculates which lines of text to display.

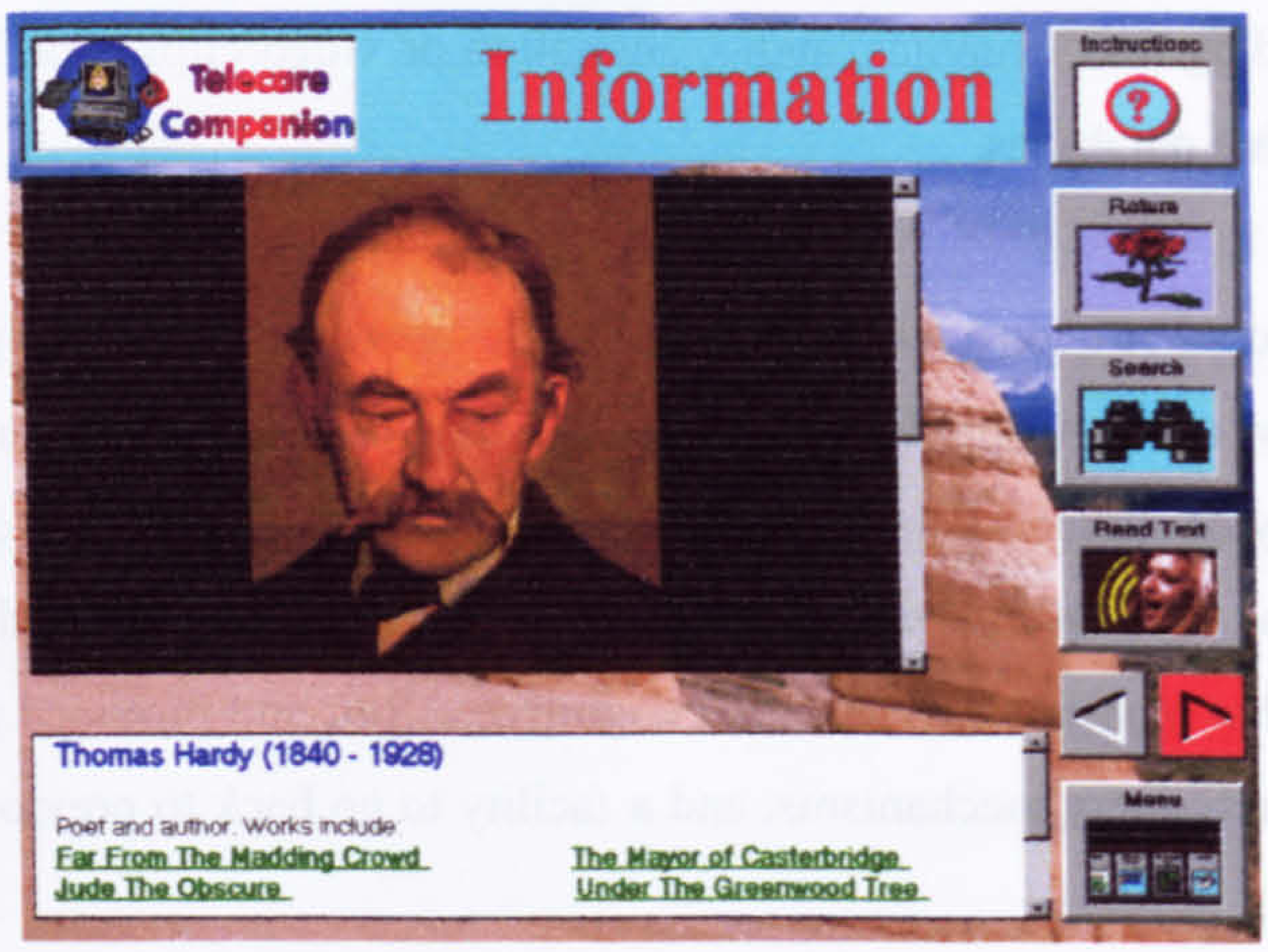


Figure 25: Image information interface

Where the *item of information* contains an image or video the images are displayed in the picture box window and a corresponding text file is shown beneath the window. This text file contains any links associated with the image (figure 25).

Users are able to step through all the *items of information* within the current topic by clicking on the *Next* button (the next chapter gives more details about the selection of *items of information*).

Users are able to search for *items of information* in a number of ways. It is possible to browse through the contents of the hierarchy of subjects, topics and sub-topics or of an alphabetical index (figure 26). Users can also view a list of all previously viewed *items of information* in the current session or in all sessions. There is also an option for users to enter a word or phrase to search for in all the text files. The results of each type of search form a list of all *items of information* that satisfy the search requirement that users can browse through and select.

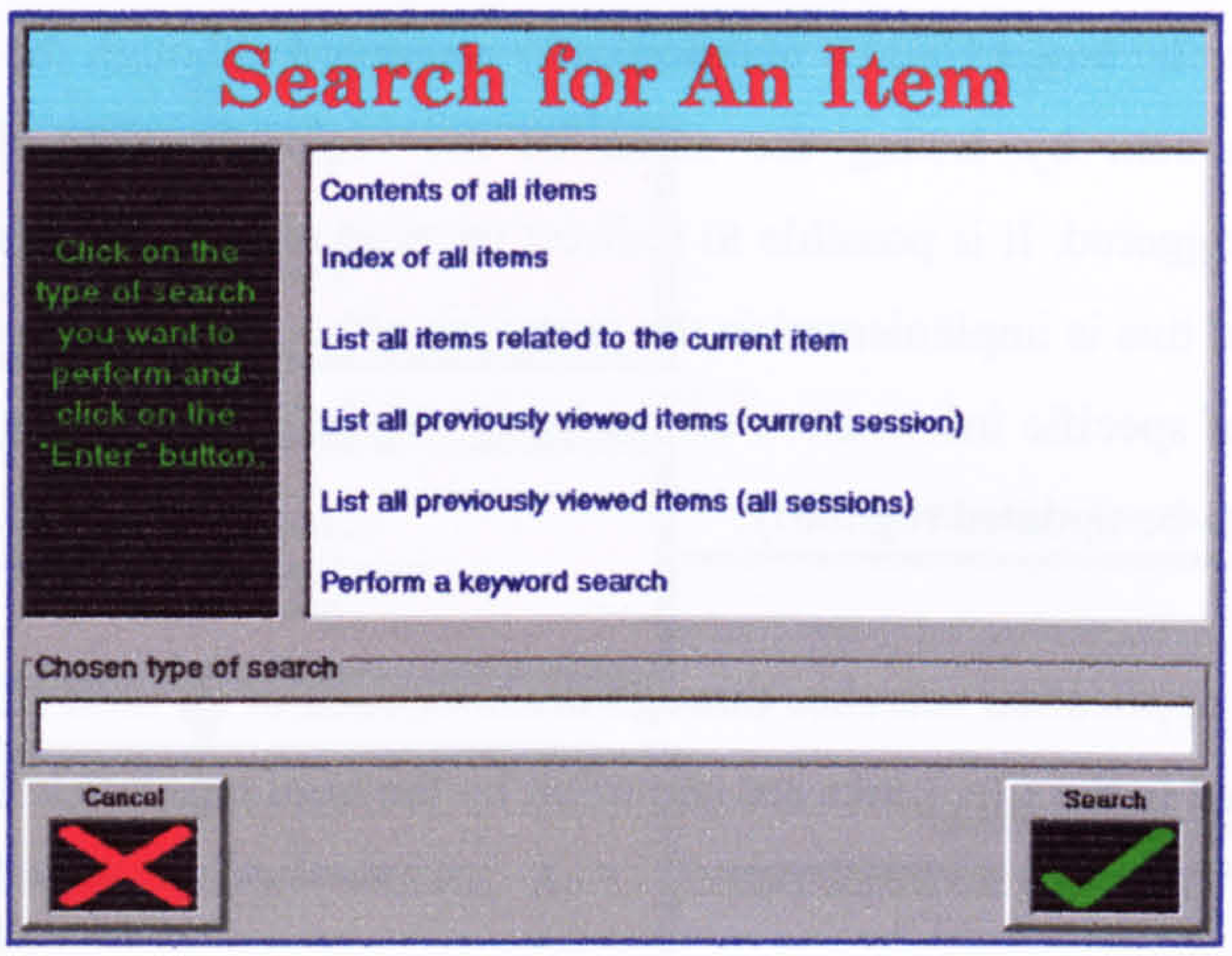


Figure 26: Search interface

2.2.4.3 Access to the Internet

Figure 27: Internet interface

Remote information on the Internet is accessed using the *NetManage* HTML control that is placed on the screen like a Text Box but has extra programmable methods that enable access to the Internet. HTML pages are displayed in the same manner as Internet Browsers (figure 27). One limitation, however, is that the control only handles plain HTML and does not handle Java applets, JavaScript or VB Script. Users can navigate through the Internet by clicking on the highlighted hyperlinks in the same manner as an Internet Browser. Blue highlighted words represent the links that the user has not yet visited while the purple highlighted words represent the links that users have already visited.

The application can request specific URLs by passing the name of the URL to the HTML control *RequestDoc* method:

```
HTML1.RequestDoc "http://www,bournemouth.ac.uk"
```

When users click on links the target URL is automatically requested although the programmer can intercept the request before it is sent by testing the name of the requested URL when the HTML control *DoRequestDoc* event is triggered. It is possible to redirect users to alternative locations if specific URLs are requested. One example of this is implemented in the prototype although it is unlikely that this feature will be widely used. The URLs of specific information on the World Wide Web are constantly changing and so the list of URLs would have to be updated regularly.

The *Telecare Companion* application searches through the html code of all html files that are displayed to list all the hyperlinks contained in the file. Links are identified by the html tags "<a href":

```
Position1 = InStr(sourceText, "<A HREF=""")
```

The text contained between quotation marks following the *href* tag refers to the target URL of the hyperlink. These addresses are copied from the HTML file and placed in a database. The links are printed at the bottom of the screen in groups of four that the user can be step through (figure 27). Users can select individual links from this list by clicking on the desired link in the same way as selecting a hyperlink. This feature allows voice commands to be associated with the buttons so users can use voice commands to step through the links and select a link by asking for the first second, third or fourth link that is currently being displayed. Therefore *Telecare Companion* makes it is possible for users to browse the Internet using only voice commands without using the mouse. The method of extracting links from the HTML file and enabling the Internet to be browsed using voice commands was an innovation that is unique to the prototype.

The text of the HTML file without the HTML tags is placed in the hidden text box that allows the text to be read out by the text-to-speech application:

```
txtSpeech.Text = HTML1.GetPlainText(0, 0)
```

2.2.4.4 Personal information

The personal information facility allows users to store text, images, audio & video information such as personal details about themselves, their medical condition, and details about family and friends. This information is used by the system to identify information that may be relevant to the user's special needs and contact people in the family and friends database. This also allows the user to personalise their system. The data placed in the *Personal Information* database is explored in chapter 3 and the information placed in the *Family and Friends* database is explored in chapter 4.

2.2.5 States of the system

The *Telecare Companion* system is designed to be on at all times in the users home and so there a number of stages that the system goes through while not being operated by the user (figure 28).

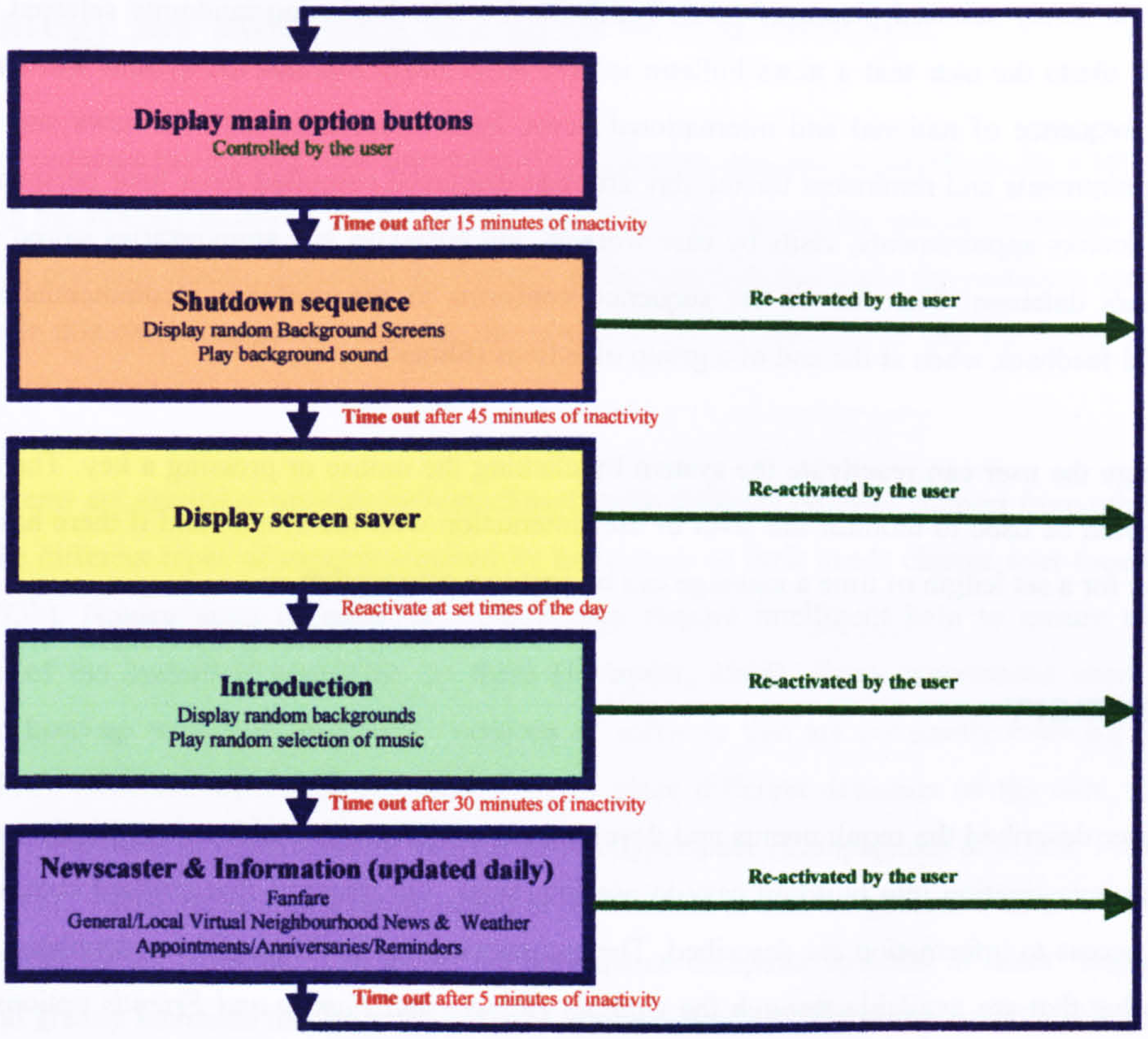


Figure 28: States of the system

The normal state is when the system is being operated by the user. After 15 minutes of user inactivity the system is timed out into the shut down sequence. The screen displays only the seven main option buttons of the system while the background image is randomly changed and an ambient sound effect is played (the sound of the sea, rain, birdsong etc.) to indicate that the system is still running.

After 45 minutes the shutdown sequence is timed out and the screen saver image is displayed floating diagonally across a blank screen (figure 29). The screen saver image moves around a blank screen until the system is reactivated by the user or activated by a timer event.

Figure 29: Screen saver

At set times of the day such as eight in the morning and six in the evening, providing that the user is not activating the system manually, the system will automatically be reactivated. For thirty minutes the system will play randomly selected pieces of music (midi files) while displaying randomly selected backgrounds. The music alerts the user that a news bulletin is due. After thirty minutes the system will start. A fanfare starts the sequence of national and international news, local community network news and weather. The user's appointments and reminders for the day are then displayed compiled from their personal information detailing doctors appointments, visits by care workers and birthdays and anniversaries stored in the *Family and Friends* database. The end of the sequence conforms to the usability recommendation to provide meaningful feedback when at the end of a group of actions (Shneiderman, 1998).

At any stage the user can reactivate the system by clicking the mouse or pressing a key. The auto-presence features could be used to monitor the level of user interaction with the system and if there has been no user interaction for a set length of time a message can be sent to a care worker.

2.3 Summary

This chapter described the requirements and development of a prototype telecare system that was created as part of the investigation into building easy-to-use interfaces. The features that enabled communication and provided access to information are described. The communication facilities of the videophone, audio phone, and text chat that are available through the *Contact Helpers* and *Family and Friends* options. Information that is presented to users is available through the *Information and Newscaster*, *Hobbies* and *Special Needs* options. Information stored by the user can be browsed and edited through the *Personal Information* and *Family and Friends* options.

The features that make the system easy-to-use include:

- The clear, consistent uncluttered layout screens
- The design of large buttons, with extra functionality
- Navigation using the buttons and menu bar
- The communication facilities are reached in few simple steps
- Use of audio and text-to-speech to present information
- The implementation of voice commands
- The *companion* personality used to present information and help

Only the static features are described in this chapter, while the dynamic adaptive features are described in the next chapter.

3 A strategy for adapting features of a prototype

This chapter continues the investigation into methods of creating easy-to-use interfaces for a telecare system by examining the strategy followed in adapting aspects of the interface of the telecare prototype described in chapter 2. The previous chapter described the features of the interface that make the prototype easy-to-use for all users while this chapter examines the way the interface can be changed to suit the needs of individual users.

Adaptive systems are needed to provide individual users with different types of support from other users and to provide the different types of support required by individuals as their needs change over time (Benyon & Murray, 1993b). Novice users of complex systems may require intelligent help to ensure that the full functionality of the system is accessible by them (Helander, 1988). Even experienced users may need assistance to keep up with new 'improved' versions of software that are constantly evolving (Benyon & Murray, 1993b). Different aspects of computer systems place different demands on the user, for example there is danger that users of hypertext will become lost in hyperspace (Campagnoni & Erlich, 1989; Conklin, 1987; Rossi et al., 2000). By adapting the selection of information to suit the goals and aims of the individual will reduce information overload. The ability to personalise computer systems to users' requirements is important and greatly increases the desirability of the system (Hook, 2000). Automatically changing aspects of the interface removes some of the burden that is placed on the user to learn the whole system before they are able to customise it to suit their particular requirements (Benyon & Murray, 1993a).

The prototype telecare system has a number of aspects that may benefit from the application of an adaptive strategy. It is expected to be number of different types of user, ranging from novice computer users to professional users. Similarly the system is expected to cater for a wide range of user disabilities including differences in eyesight and movement abilities. Each type of user will require different types of assistance. The system also makes extensive use of hypermedia to present information and so the automatic selection of information based on the individual requirements of users may prevent them becoming lost in hyperspace.

The prototype telecare system has some *adaptable* features that are controlled by the user entering their preferences and some *adaptive* features that are automatically controlled by the system without the user needing to direct the interaction. The adaptable and adaptive features were implemented in different phases of development of the prototype:

- The adaptable features that enable the system to be personalised by the user.
- The adaptive selection of information that suits the goals and knowledge of the user.
- The adaptive style presentation of information that suits the cognitive style (CS) of users.

This chapter discusses the adaptable and adaptive features that were implemented in each stage of development. Firstly the adaptable features including the selection of the font size and the selection of background features, and secondly the adaptive features including the mechanism used to select and present information for individual users.

3.1 Adaptable aspects of the interface

The adaptable aspects are the features that the user expressly controls by setting preferences. Setting the *User Preferences* allows the user to configure important screen design aspects such as the font size and also to reflect their own personality.

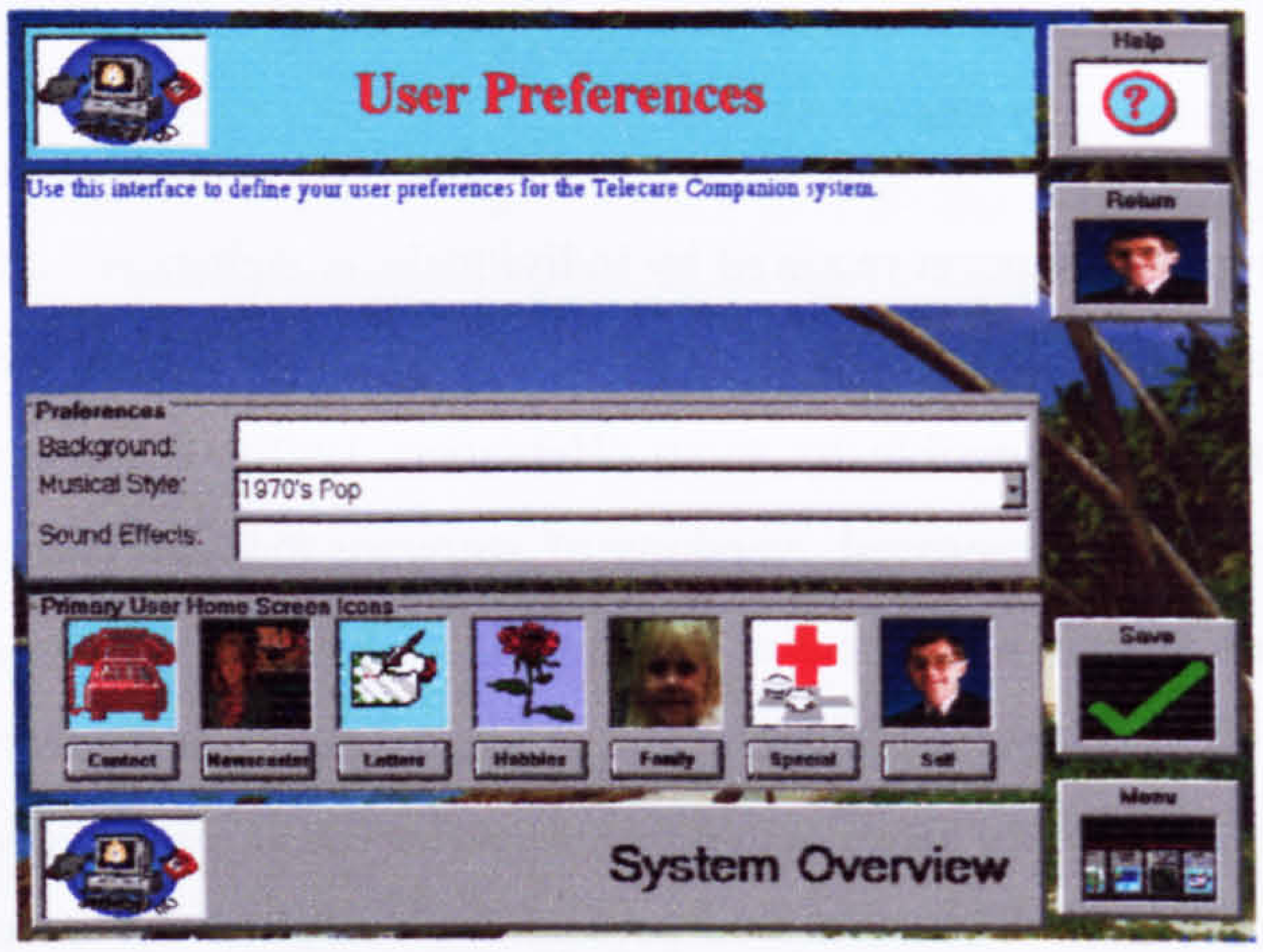


Figure 30: User Preferences screen

In the telecare prototype user preferences can be entered through the *User Preferences* screen (figure 30) within the *Personal Information* option and through the *Medical Details* screen (figure 31) within the *Special Needs* option.

The *User Preferences* screen (figure 30) allows users to specify their preferred choice of *backgrounds*, *musical style*, *sound effects* and the images used in the option buttons. The choice of *backgrounds* refers to the collections of images that users can view through the *Gallery* (figure 33) available in the *Hobbies* option. The choice of *backgrounds* can be set by directly through the *User Preferences* screen automatically by the system as it monitors the users' choices when browsing through the *Gallery* (section 3.1.2). The screen backgrounds are changed at random from within the chosen category while the system is in the *shutdown sequence* and *introduction* states (section 2.2.5).

The choice of *musical style* refers to collections of midi files that the user can browse through the *Music* option (figure 34) available in the *Hobbies* option. The choice of *musical style* can also be set directly through the *User Preferences* screen or while the user browses through the collections of midi files (section 3.1.2). The system selects midi files at random from within the chosen category to play while the system is in the *introduction* state (section 2.2.5).

The *sound effects* are the ambient sounds played while the system is in the *shutdown sequence* state (section 2.2.5). The prototype allows users to choose between the sound of waves, birdsong or browse for another wave file of their choice.

Users can also specify which images to place in the main option buttons by browsing for bitmap files. This helps users to personalise the system to reflect their own personality. One recommendation when the system is being configured is for users to take images of themselves to place in the *personal information* button. The other preferences entered in the *medical information* option are described in the next section.

3.1.1 Preferences relating to medical information

Three categories of user medical information can be entered through the *Medical Information* screen (figure 31) that effect the design of screens elsewhere in the system in the same manner as specifying the user preferences.

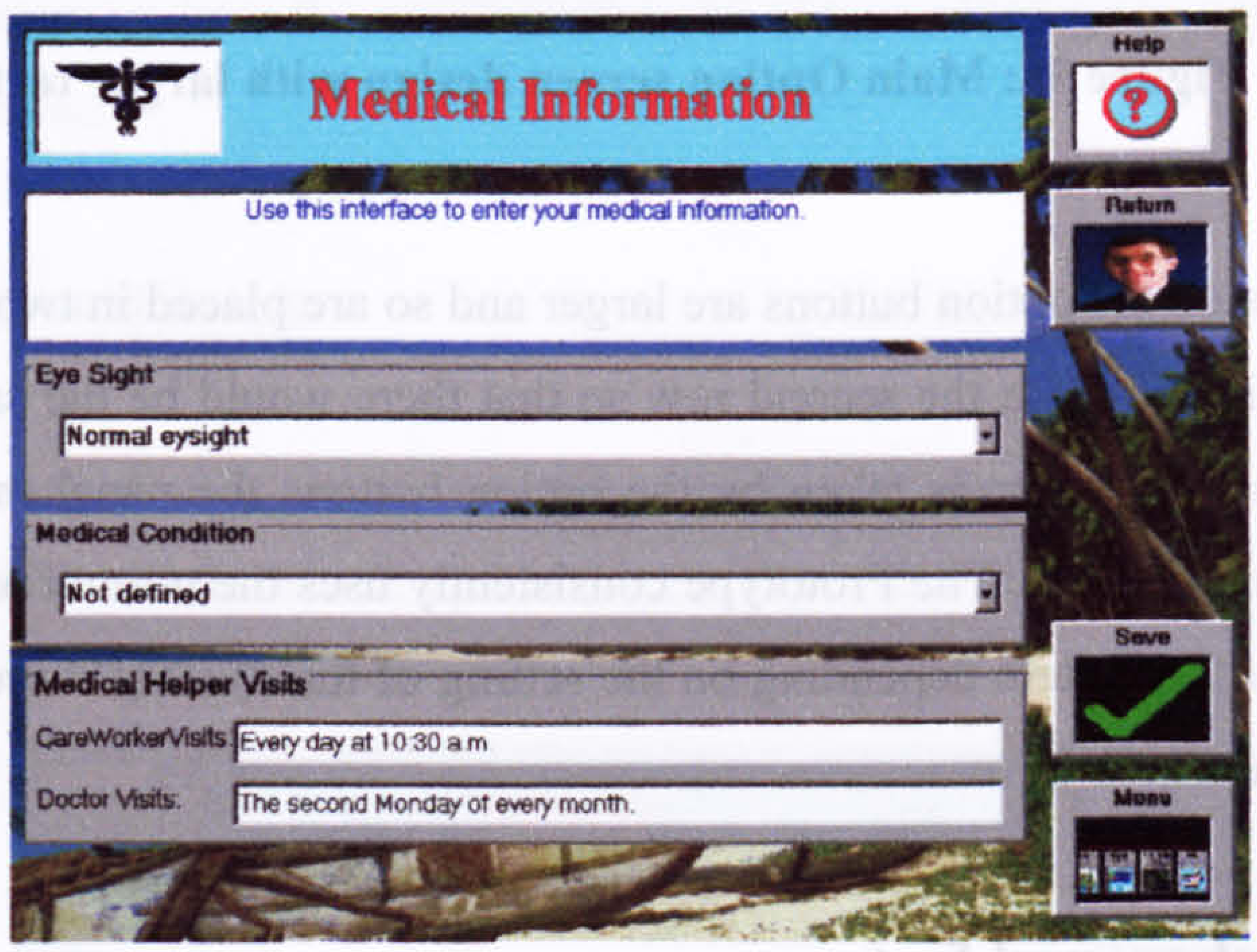


Figure 31: Medical Details screen

The *Medical Helper Visits* information (bottom option figure 31) is used by the system to compile list of user appointments that are displayed to the user while in the *Newscaster and Information* state (section 2.2.5).

The *Medical Condition* information (middle option figure 31) is used by the system to select the first piece of information that is to be presented when the user selects the *Special Needs* option. The prototype contains a number of HTML files relating to different medical conditions containing links to relevant sites on the Internet. When the user requests the *View Medical Information* option from the *Special Needs* screen the HTML file that best suits their medical condition is selected.

The *Eye Sight* preference (top option figure 31) conforms to the usability recommendation to allow users to specify whether they view normal or large text (Edwards, 1995). As telecare applications are designed to be operated by the elderly or disabled it is likely that many would have poor eye-sight. Therefore the *Eye Sight* preferences allows users to specify whether they have *Normal eyesight* or *Require larger text*. When each screen becomes active the *Eye Sight* preference value is examined in order to set the appropriate font size. The font size is set to 12 for *Normal eyesight* and 24 for *Require larger text*. In addition, the normal font size *Main Option* screen (figure 10) is redesigned for the larger text option (figure 32).

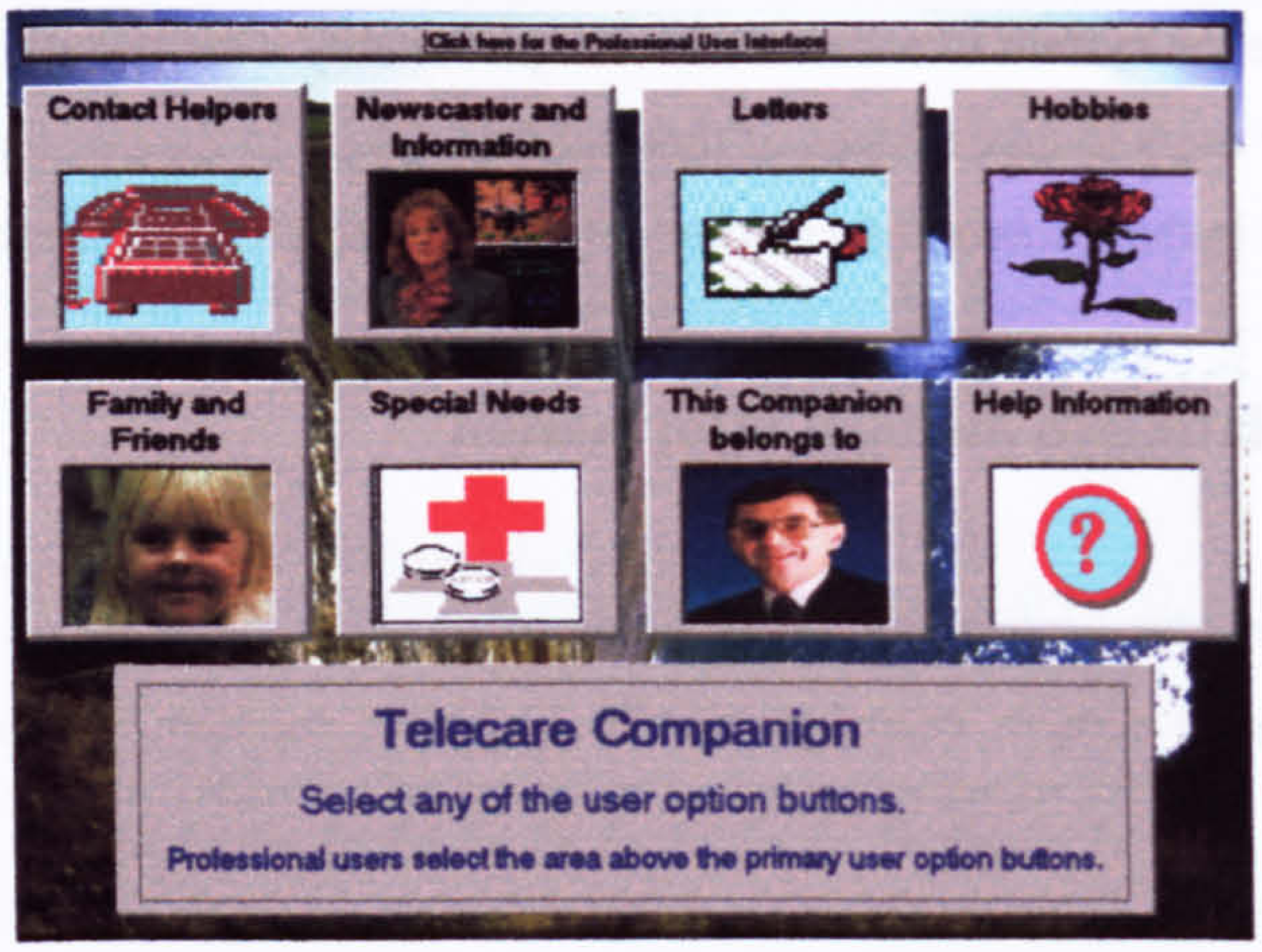


Figure 32: Main Option screen design with larger text

In the larger font size version the option buttons are larger and so are placed in two rows in order to fit on the screen. The *Help* button is moved to the second row so that there would be the same number of buttons on each row (figure 32). As more room is taken by the option buttons the panel that displays information is reduced in height but is made wider. The Prototype consistently uses the normal or larger font size for labels and text boxes throughout the system depending on the setting of the *Eye Sight* preference but only the main option screen has a different layout.

3.1.2 Selection of background features

The prototype contains a number of background features that are used to personalise the system to the users' taste or provide navigational information, such as using different backgrounds to indicate which section of the program is currently being displayed or the use of different audio cues to indicate when the system switches to another state (section 2.2.5).

3.1.2.1 Selection of background images

Background images are used to give the screen a distinctive appearance which is different from the majority of Windows based programs. Users are able to personalise the interface by selecting their preferred category of background image. The user preference of *background* can be set either explicitly using the *User Preferences* screen or by browsing through the images in the *Gallery* option (figure 33) available in the *Hobbies* option.

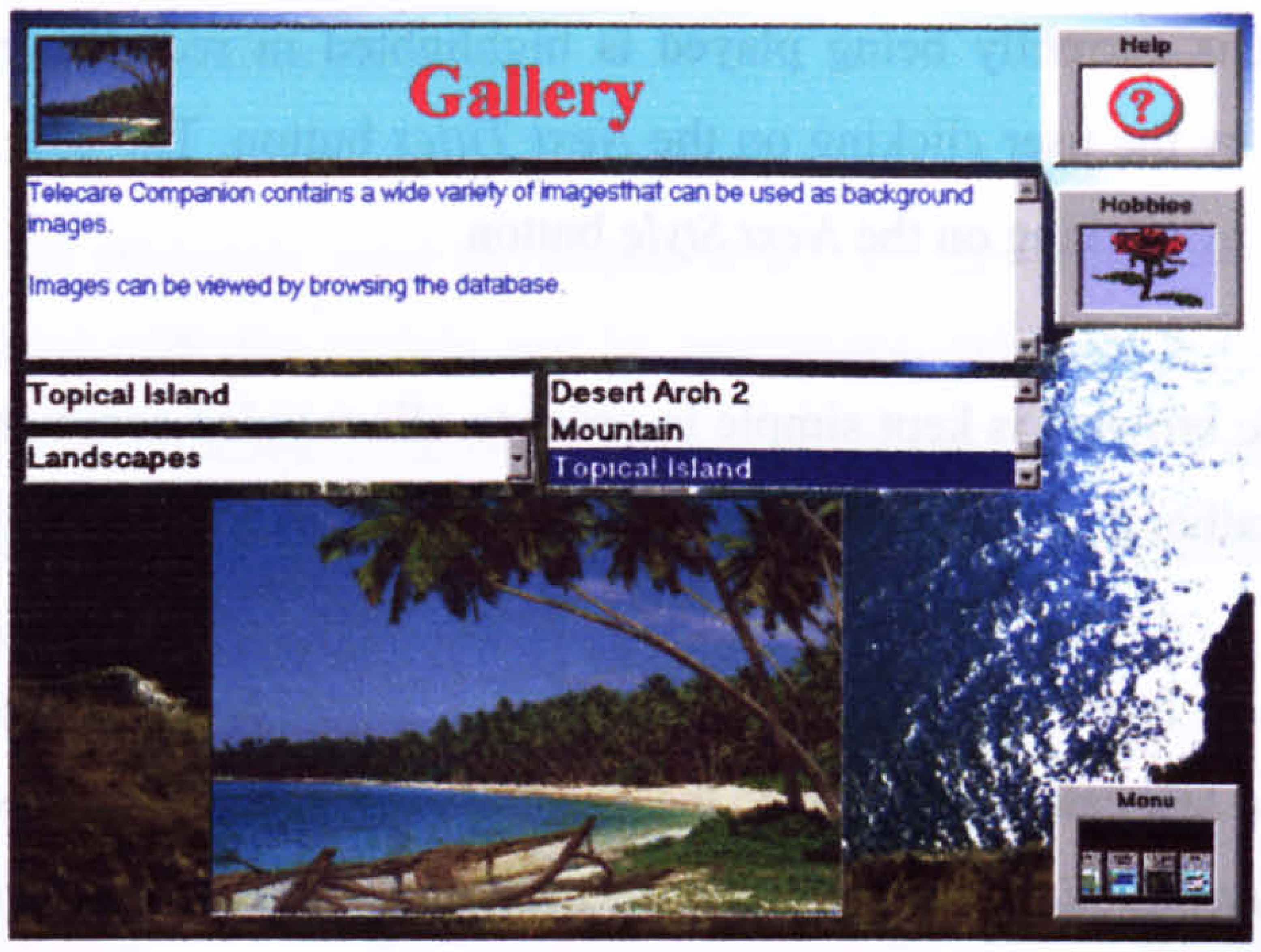


Figure 33: Gallery browser

The prototype contains five different collections of images that users can browse through as part of the *Hobbies* option; *Landscapes*, *Locations*, *Wildlife*, *Flora* and *Space*. After the user has finished viewing a selection of images the system updates the user's preference of type of image by selecting the last category of image that the user has viewed.

3.1.2.2 Selection of background music

The user preference of *musical style* can be set either explicitly using the *User Preferences* screen or by browsing through the midi files in the *Music* option (figure 34) available in the *Hobbies* option.

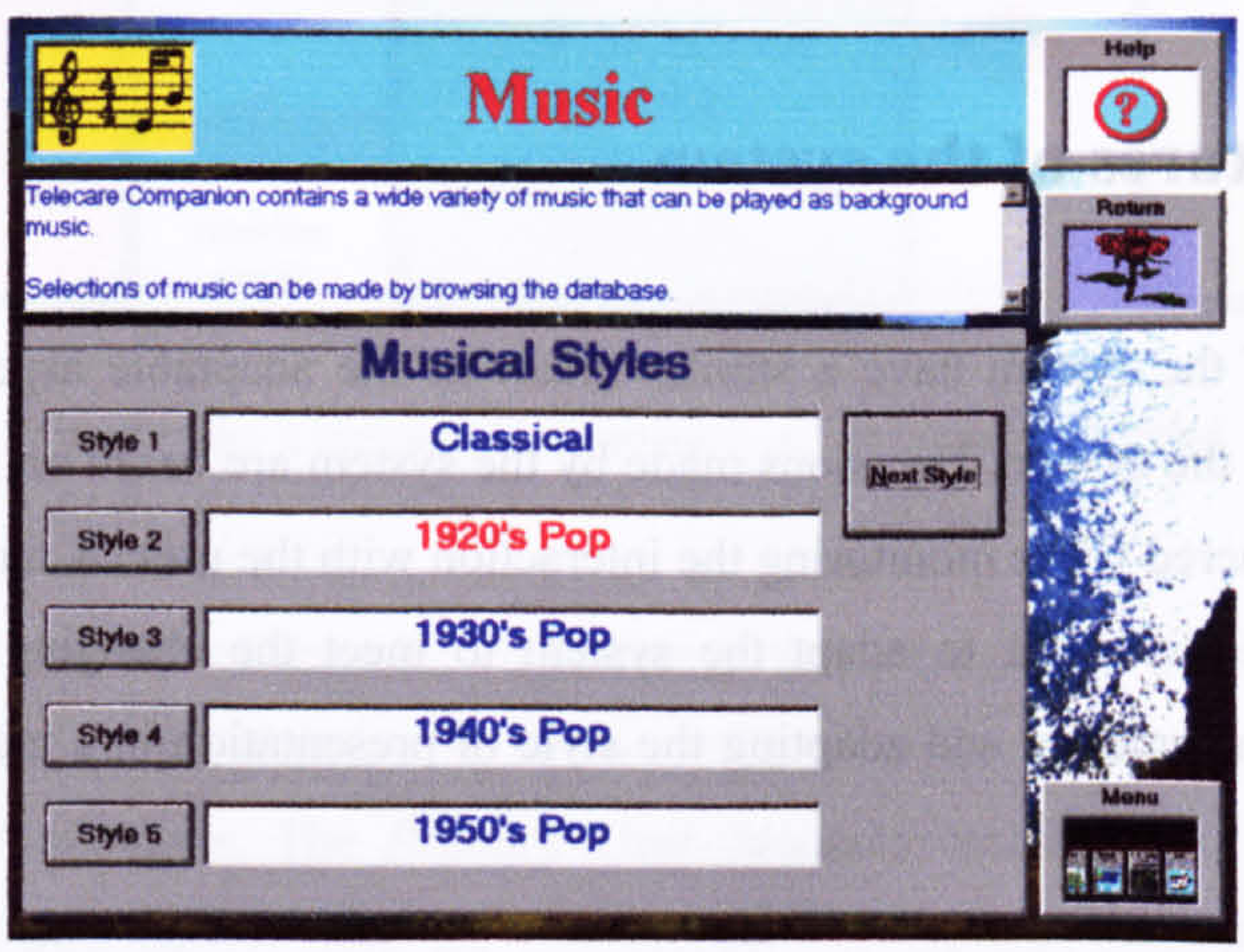


Figure 34: Music styles browser

The prototype contains a collection of midi files that users can browse through as part of the *Hobbies* option. The midi files are split into categories such as *Classical*, *1920's Pop*, *1930's Pop*, *1940's Pop*, *1950's Pop*, etc. The titles of the different categorises can be browsed by user clicking on the *Next Style* button (figure 35). When the user selects a category of music the song titles are available to select using the interface shown in figure 35. Individual songs can be selected by the user to play by clicking on the five song buttons or the song title. The song that is currently being played is highlighted in red. Other songs within the current category can be browsed by the user clicking on the *Next Titles* button. The user can get back to the *music styles* browser (figure 34) by clicking on the *Next Style* button.

The interface of the *Music* browser is kept simple in order to allow voice commands to be associated with a small number of buttons rather than the title of each individual midi file.

After the user has finished browsing through the midi files the system updates the user's *musical style* preference by selecting the last category of music that the user has chosen. The next time the system selects a tune to play while in the *introduction* state it will be selected from this category of music.

Figure 35: Music song titles browser

3.2 Adaptive Features of the system

The adaptive features of the system have a similar effect as the adaptable aspects of the system but are automatically updated by the system. Decisions made by the system are based on information entered by the user and information gathered while monitoring the interaction with the user. A range of methods of adapting the system were explored in order to adapt the system to meet the changing needs of users including automatically selecting information and adapting the style of presentation in a manner that is appropriate to the individual user.

The selection of information to present was adapted to individual users by matching the available material with the individual's aims and current state of knowledge. The adaptive mechanism for selecting information is described in section 3.2.1. The presentation style was adapted to individual users by adjusting the presentation environment to suit their CS. The presentation features are described in section 3.2.2.

3.2.1 Adaptive selection of information

The adaptive features of the prototype were developed following the principles illustrated by figure 1 in chapter 1. The user interacts with the system and by monitoring this interaction a model of the user is assembled by the system. The selection of information that is presented to the user depends on the values held in the user model. The adaptation process is dynamic as user actions are influenced by information that is displayed by the system. Selection of the information that is displayed and the style of presentation are selected by the system in response to the user actions.

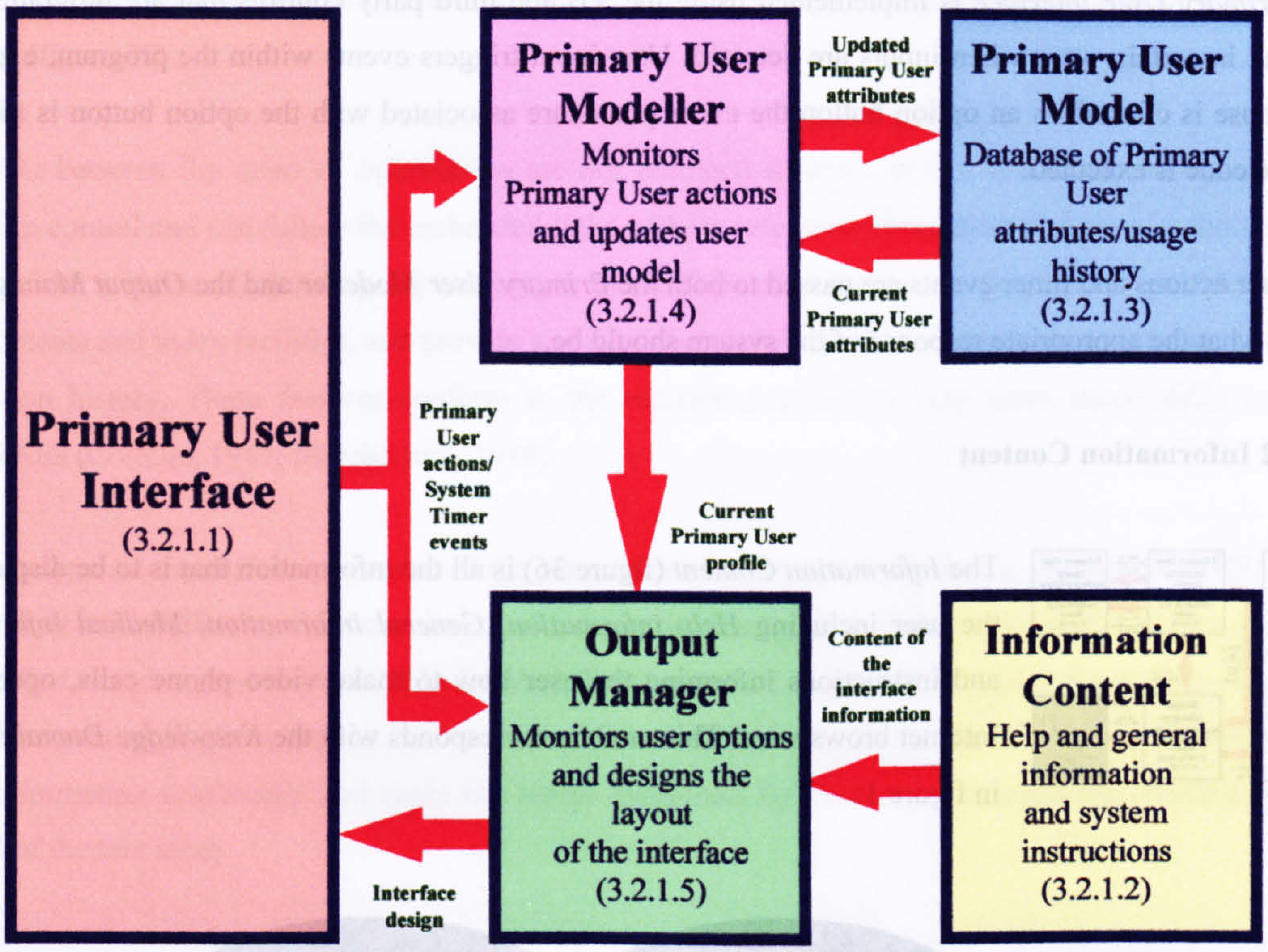
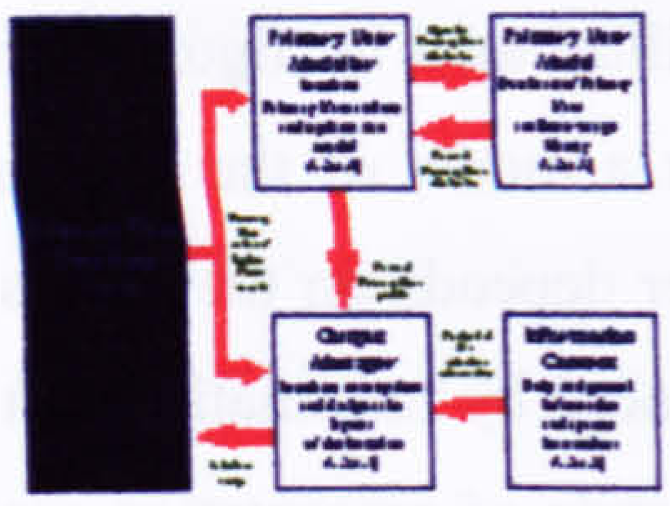


Figure 36: Telecare Companion adaptation modules

Figure 36 shows how the modules of the telecare prototype that are concerned with adaptivity interact with each other. User actions that are detected by the *Primary User Interface* are processed by the *Primary User Modeller* and the *Output Manager*. The *Primary User Modeller* updates the *User Model*. The *Output Manager* selects *items of information* from the *Information Content* that suits the *Current Primary User Profile* and presents them to the user through the *Primary User Interface*. The following sub-sections describe the processes involved in each module (the numbers displayed in figure 36 refer to the sub-section numbers). The diagram at the start of each sub-section highlights the module being described in relation to figure 36.

3.2.1.1 Primary User Interface

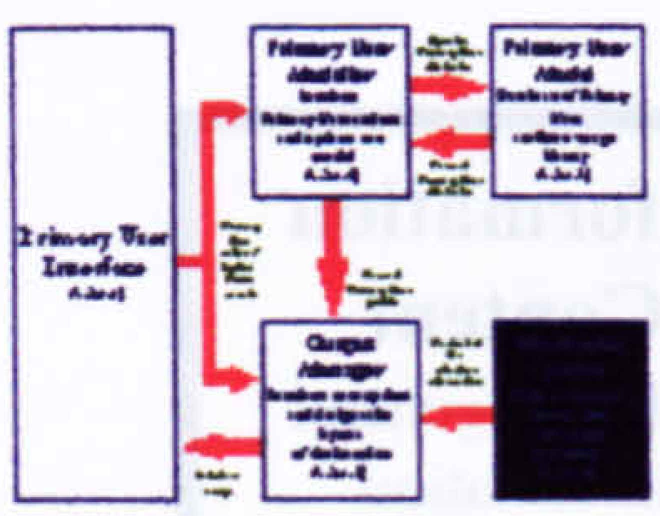


The *Primary User Interface* (figure 36) is the interface between the system and the user. This includes the output devices that display information to the user (through the screen, speakers or printer) and the devices that detect input from the user (through the keyboard, mouse or voice commands). The input also includes the events triggered by timers (events programmed to occur at set times of the day or at times relative to other events).

The *Primary User Interface* is implemented using the VB and third party controls that are programmed to respond in certain ways when inputs are detected. User input triggers events within the program, e.g. when the mouse is clicked on an option button the event procedure associated with the option button is triggered and the code is executed.

The user actions and timer events are passed to both the *Primary User Modeller* and the *Output Manager* that assess what the appropriate response of the system should be.

3.2.1.2 Information Content



The *Information Content* (figure 36) is all the information that is to be displayed to the user including *Help information*, *General information*, *Medical information* and instructions informing the user how to make video phone calls, operate the Internet browser etc. This module corresponds with the *Knowledge Domain* shown in figure 1.

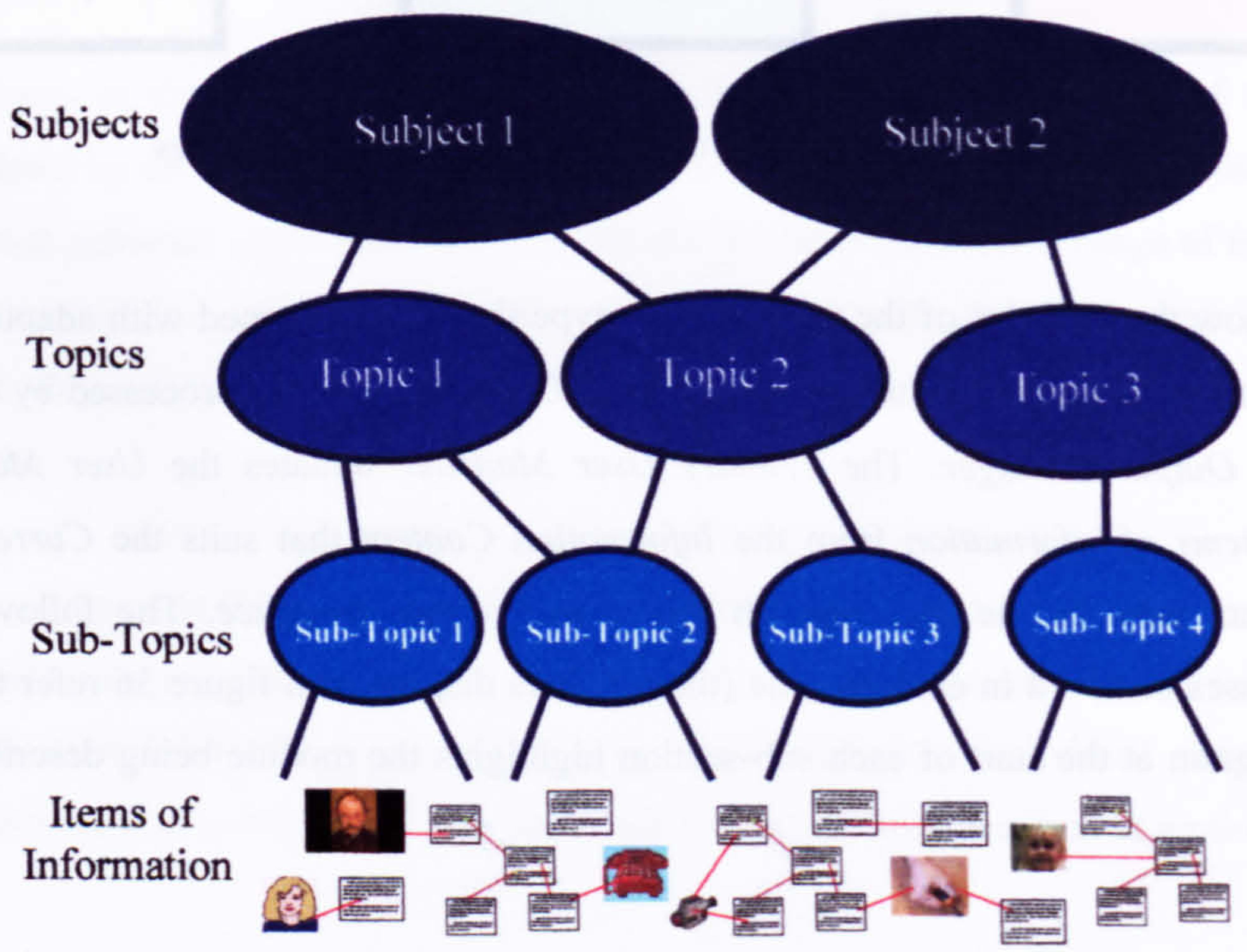


Figure 37: Hierarchical structure of the Information Content

The *Information Content* of *Telecare Companion* consists of a hypermedia network (figure 37). The hypermedia network contains individual nodes (*items of information*) which may be text, image, audio or video files, with links between the nodes (implemented by storing the links in an external Access database).

A hierarchical structure is imposed over the hypermedia network to aid navigation through the information. The *items of information* are at the bottom of hierarchy. Related *items of information* are grouped together within *sub-topics*, the *sub-topics* are grouped together within *topics*, that are in turn grouped together within subjects. Individual *items of information* may be within a number of different *sub-topics*, individual *sub-topics* may occur in a number of different *topics*, and individual *topics* may occur in a number of different *subjects* (figure 37).

The links between the *items of information* are not confined to items within the same *sub-topics*. Users remain in control and can follow the embedded links without reference to the hierarchy, or can choose items directly from a hierarchical listing. By defining a subject hierarchy it has been possible to provide the user with contents and index facilities, and provide a context for the results of word searches and the user's system interaction history. These features conform to the recommendations to help users successfully navigate hypermedia (Conklin, 1987; Marchionini, 1988).

The prototype selects different versions of the same *item of information* depending on the users' CS. Figure 38 illustrates the difference between items of information designed to suit Verbalisers and Imagers. The version that was designed to be suitable for Verbalisers uses text only and the hyperlinks are represented by underlined text highlighted in blue. The version that was designed to be suitable for Imagers represents the same information graphically and users can select hyperlinks by clicking on images representing the link instead of the text label.

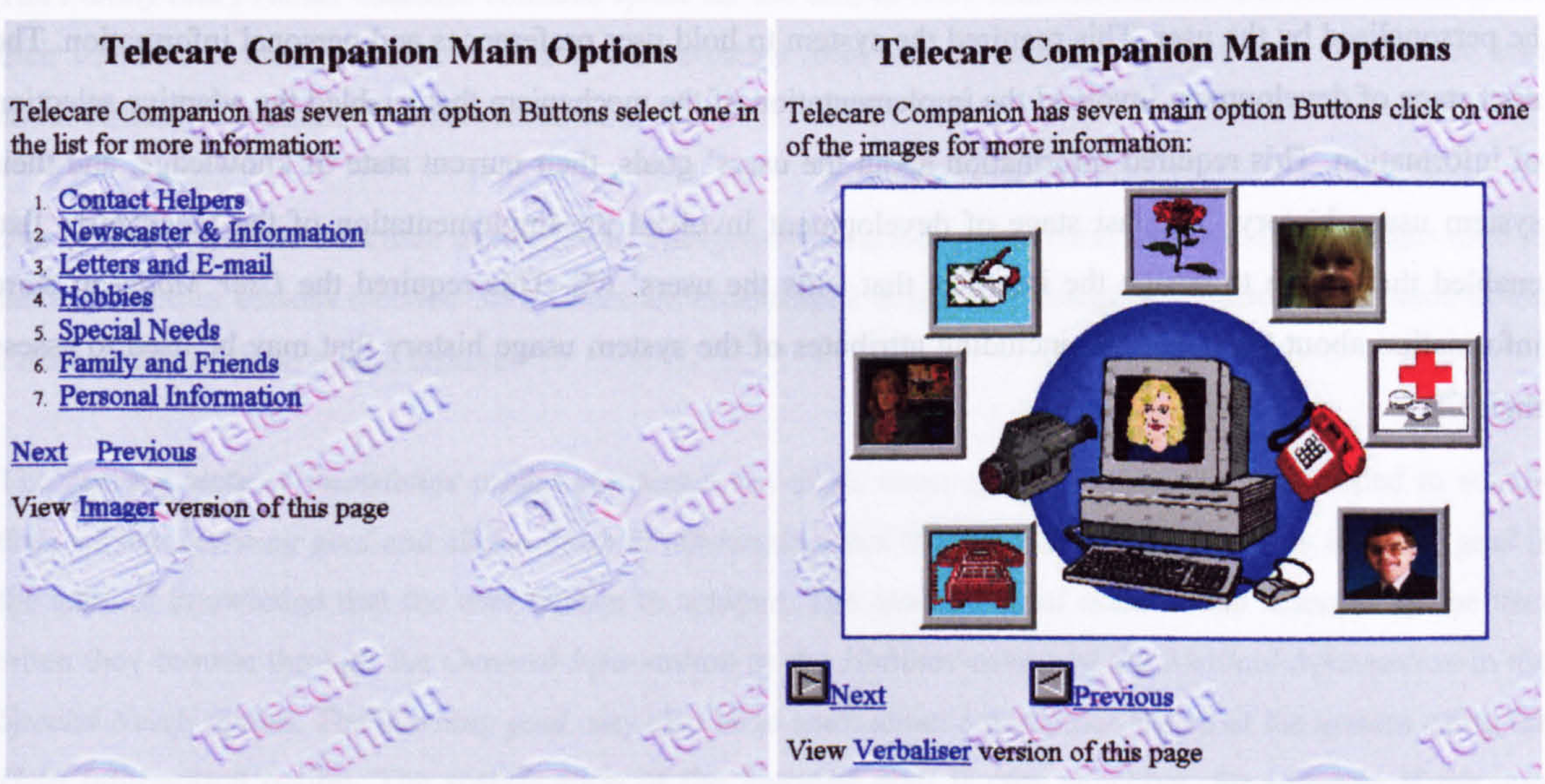
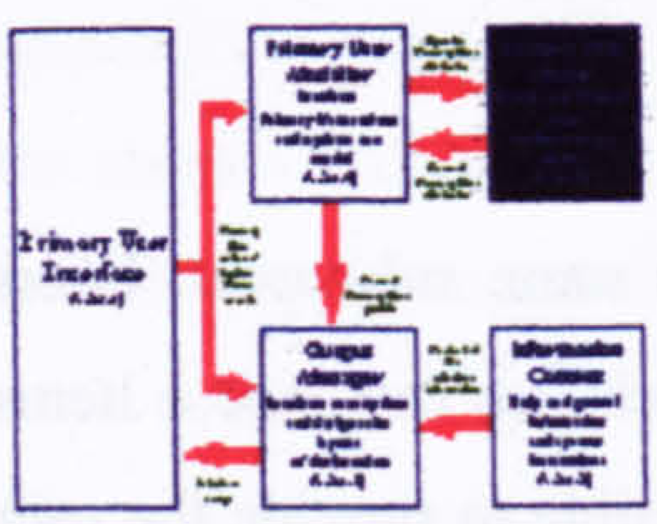


Figure 38:Verbaliser and Imager versions of information files

There are four main categories of CS (section 1.2.3) and so there are four possible alternative versions of the same *item of information* for Wholist/Verbalisers, Wholist/Imagers, Analytic/Verbalisers and Analytic/Imagers. The difference between the Verbaliser and Imager versions, as shown above, is the use of text and images, while the difference between the Wholist and Analytic versions is how the information is structured. The alternative versions of the *items of information* contain the appropriate characteristics that are suitable for both dimensions.

3.2.1.3 Primary User Model



The *Primary User Model* (figure 36) is a collection of databases that contain all the information about the user that the system needs in order to adapt the system to suit their individual needs. The *User Model* contains the information that the system "knows" about the user that forms the *Current Primary User Profile*. The *Primary User Modeller* and the *Output Manager* contain the functionality that manipulates the *User Model* and adapts the output of the system to suit the *Current Primary User Profile*.

Some of the data is explicitly input by the user in order to personalise the interface to their own specification while other data are implicitly inferred by the *Primary User Modeller* by monitoring their interaction with the system. The information contained in the *User Model* is used by the *Output Manager* to select information that meets the user's needs and to design the interface in a manner that the user will understand.

The information that is stored in the User Model can be grouped into the following sub-models; the *users' personal information*, their *current state of knowledge*, their *system usage history* and their *cognitive style*, (figure 39). The categories of information contained in the *User Model* evolved during the different stages of the development of the prototype. The first stage involved setting up a mechanism that enabled the system to be personalised by the user. This required the system to hold user preferences and personal information. The next stage of development involved the implementation of the mechanism that enabled the adaptive selection of information. This required information about the users' goals, their current state of knowledge, and their system usage history. The last stage of development involved the implementation of the mechanism that enabled the system to design the interface that suits the users' CS. This required the *User Model* to store information about the users' CS including attributes of the system usage history that may be used to assess their CS.

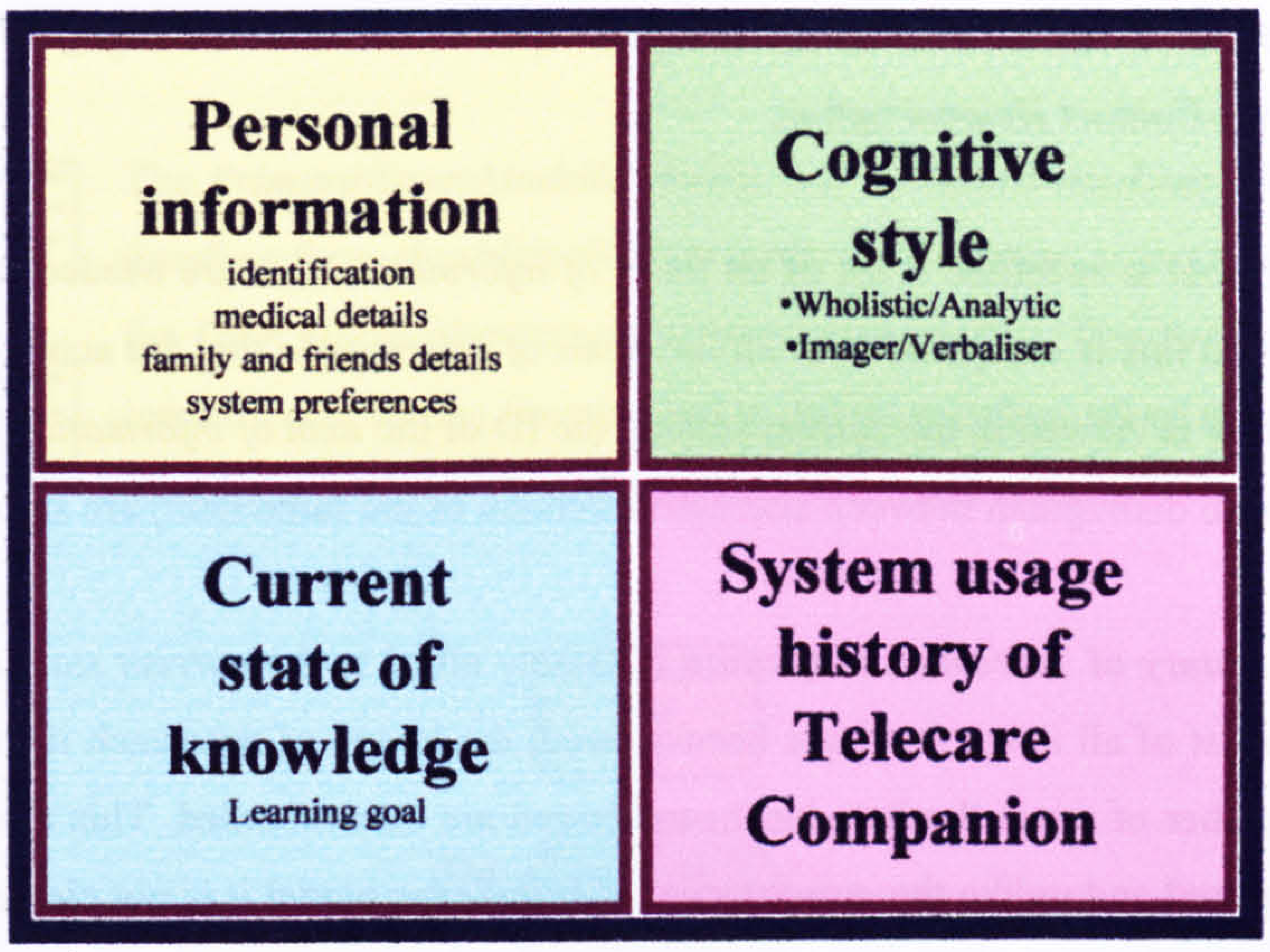


Figure 39: Contents of the User Model

The users' ***personal information*** includes their identification details, medical details, family and friends details and system preferences (figure 39). The user's identification details contains their full name (and their preferred name to be used by the system in personalised interaction), date of birth (used by the system to be calculate the user's birthday), and address (their home address and the IP number of their computer).

The users' medical details include the information used by the system to target the appropriate *Special Needs* information to the user and determine the appropriate size of font to use (section 3.1.1). The users' medical details also include the particulars of care worker visits and doctors' appointments that are shown when displaying the days' appointments and reminders (section 2.2.5).

The *Family and Friends* database contains space for the user to store multimedia files and information about their friends and family members. Details are extracted from this database by the system to remind the user about birthdays and anniversaries (section 2.2.5).

The system preferences include the choice of *background, musical style, sound effects* and the images used in the main option buttons (section 3.1). Users are encouraged to input an image of themselves to place in the *Personal Information* option button.

The ***current state of knowledge*** model contains a list of all *items of information* that are needed to satisfy their current *learning goal* and all the *items of information* that the user has viewed. A user's *learning goal* is the state of knowledge that the user wishes to achieve. The *learning goal* is indirectly selected by the user when they browse through the *General Information* in the *Hobbies* option or the *Medical Information* in the *Special Needs* option. The *learning goal* may also be to learn about a particular aspect of the system using the *Help Information* option. The specification of the *learning goal* is case sensitive, for example if the user selects the *Help* option while in the *Contact Helpers* option then the *learning goal* would be to obtain information about the *Contact Helpers* option.

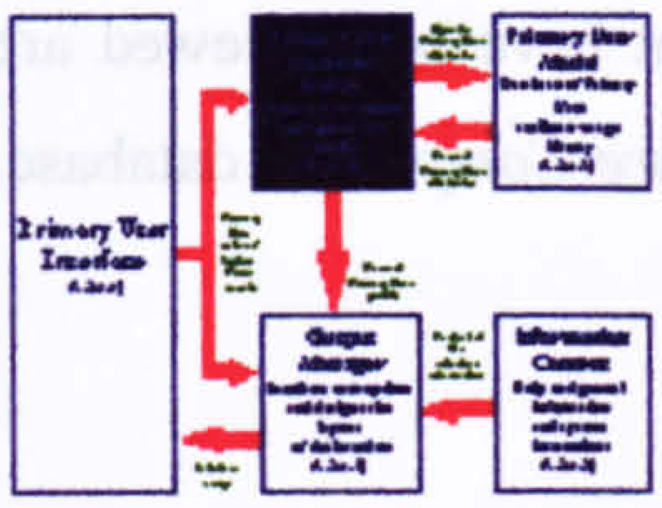
When the *learning goal* is specified a list of all *items of information* that are needed to satisfy the *learning goal* are compiled and this is compared with all the *items of information* that are actually viewed. Each time an *item of information* is viewed in the current session the ID of the *item of information* and the ID of the file containing the item (to distinguish between alternative version of the same item) are stored.

The ***system usage history*** of ***Telecare Companion*** is closely allied to the *current state of knowledge* model, but in addition to a list of all items that have been viewed, the length of time each item has been viewed in seconds and the number of times the item has been viewed are also recorded. This model is updated while the system is being used and unlike the *current state of knowledge* model it is not cleared each session. This information was not used by the prototype in the adaptation process the system but was recorded in order to analyse the actions of the user in the experiments described in chapters 4 to 8.

The user's ***cognitive style*** model is included in the *User Model* in order for the system to select the appropriate method of presenting information to the user (section 3.2.2). The CS of users can be calculated externally by the CSA test and entered through the *Personal Information* interface, or inferred by the *Primary User Modeller.*

For demonstration purposes the system attempted to make a dynamic assessment of the CS of based on the actions of the user. A series of rules were implemented based on the characteristics of the different CS groups described in the CSA literature (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1997; Riding, 1998; Riding & Raynor, 1998). Wholists are expected to gain an overview understanding of a body of information rather than concentrate on the distinction between the components and so when offered a choice between *overview* or *details* they are more likely to choose *details*. In contrast, Analytics are expected to gain an understanding of the components of the information as separate entities rather than how they fit together and so are more likely to choose *overview* than *details*. Verbalisers are expected to understand information that was presented in textual format rather than images while Imagers are expected to understand information that is presented in image format rather than text. Therefore where there is a choice between textual and visual versions of the same information Verbalisers are expected to select the text version and Imagers are expected to select the Image version. It is also assumed that Verbalisers are more likely to click on the labels on command buttons rather than the images while Imagers would click on the image. In order for the *Primary User Modeller* to make an assessment of the CS of users the *User Model* records the number of times the user performs an action that is associated with a particular CS. The assumptions about the characteristics of Wholists, Analytics, Verbalisers and Imagers that were implemented in the prototype were tested in the experiment discussed in chapter 4.

3.2.1.4 Primary User Modeller



The *Primary User Modeller* builds and maintains the *User Model* and acts as the interface through which all other parts of the system access the values contained in the *User Model* (the *current primary user profile*). The *Primary User Modeller* is implemented as one function but is distributed throughout the program in the code associated with the VB controls that detect user input.

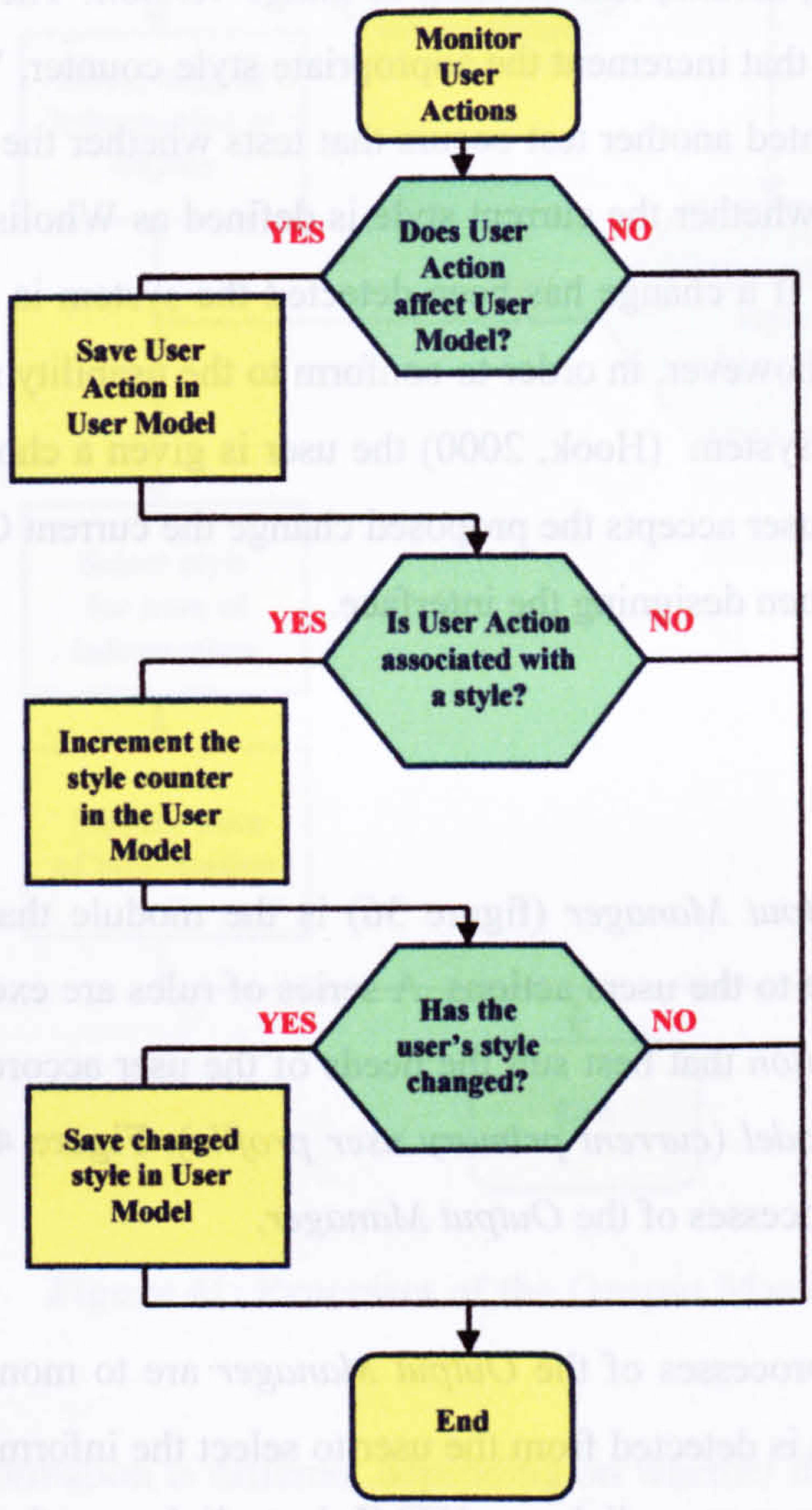


Figure 40: Processes of the Primary User Modeller

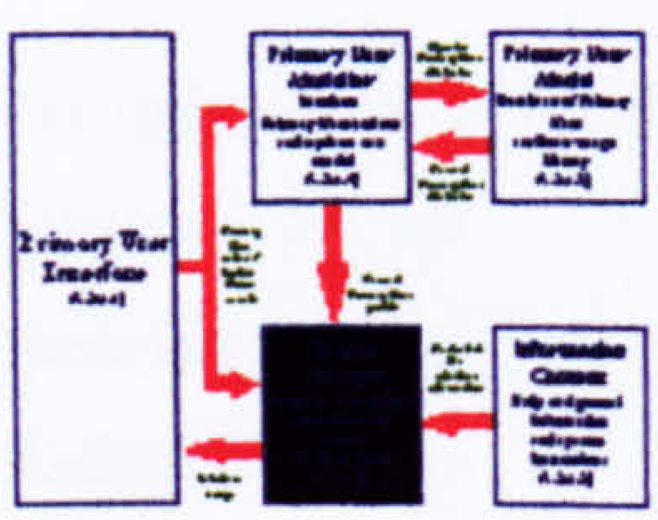
Figure 40 illustrates the way the program performs the monitoring of the user interaction and the maintenance of the *User Model*. When user input is detected an assessment is made of whether the input affects the *User Model* and the relevant information is used to update the *User Model*. This depends on the type of event that is detected. Events that affect the *User Model* such as requests for new information to be displayed (selecting hyperlinks, or the *Next* or *Previous* buttons) activate code to update the *User Model*. Events that do not affect the *User Model*, such as mouse clicks on the background image, do not activate code to update the *User Model*.

Relevant information is saved in the different categories of database. Identification details, medical details, family and friends information and systems preferences are saved in the *Personal Information* database. When browsing through the hypermedia information the *items of information* that have been viewed are recorded in the *Current state of knowledge* database and the *System usage of Telecare Companion* database. The viewing time of each *item of information* is calculated:

```
ItemTime = ItemEndTime - theStartTime
```

The test *Is User Action associated with a style?* refers to actions that are assumed to reflect the users' CS i.e. clicks on hyperlinks for *overview*, *details*, *text version*, or *image version*. The HTML control searches for these keywords and call functions that increment the appropriate style counter, Wholist, Analytic, Verbaliser or Imager. If a counter is incremented another test occurs that tests whether the relative balance between the style counters have changed (e.g. whether the current style is defined as Wholist and the Analytic counter is greater than the Wholist counter). If a change has been detected the system is able to automatically change the definition of the current style, however, in order to conform to the usability recommendations that ensure the user remains in control of the system (Hook, 2000) the user is given a choice of whether they wish the system to make the change. If the user accepts the proposed change the current CS is changed and the Output Manager takes this into account when designing the interface.

3.2.1.5 Output Manager



The *Output Manager* (figure 36) is the module that determines the appropriate response to the users actions. A series of rules are executed that select the *items of information* that best suit the needs of the user according to the values held in the *User Model* (*current primary user profile*). Figure 41 shows an overview of the main processes of the *Output Manager*.

As shown in figure 41 the main processes of the *Output Manager* are to monitor user actions and when a request to display new information is detected from the user to select the information to display. User actions to display new information include mouse clicks on HTML hyperlinks, on the *Next* or *Previous* buttons or selecting items from a list of results of a keyword search. There may be a number of different versions of each *item of information* that are suitable for users with different CSs, therefore the *Output Manager* includes a process to select the version that matches the users' CS.

The *Primary User Modeller* may change the assessment of the users' CS at any time and so the *Output Manager* has to check the CS of the user to ensure the correct version of the selected *item of information* is displayed even when new information is not requested. *Items of information* are stored in HTML files, however hyperlinks refer to the name of the *item of information*. This ensures that hyperlinks are not tied to individual files but alternative versions of the *item of information* that are suitable to the user's CS can be selected by the system. The URL specified in the hyperlink is the name of the *item of information* and so when the HTML control attempts to load the URL an error event is activated. The error event is programmed to search for the *User Model* for the user's CS and then search the *Information Content* database to select the version of the chosen *item of information* that matches their CS and to then load the chosen file.

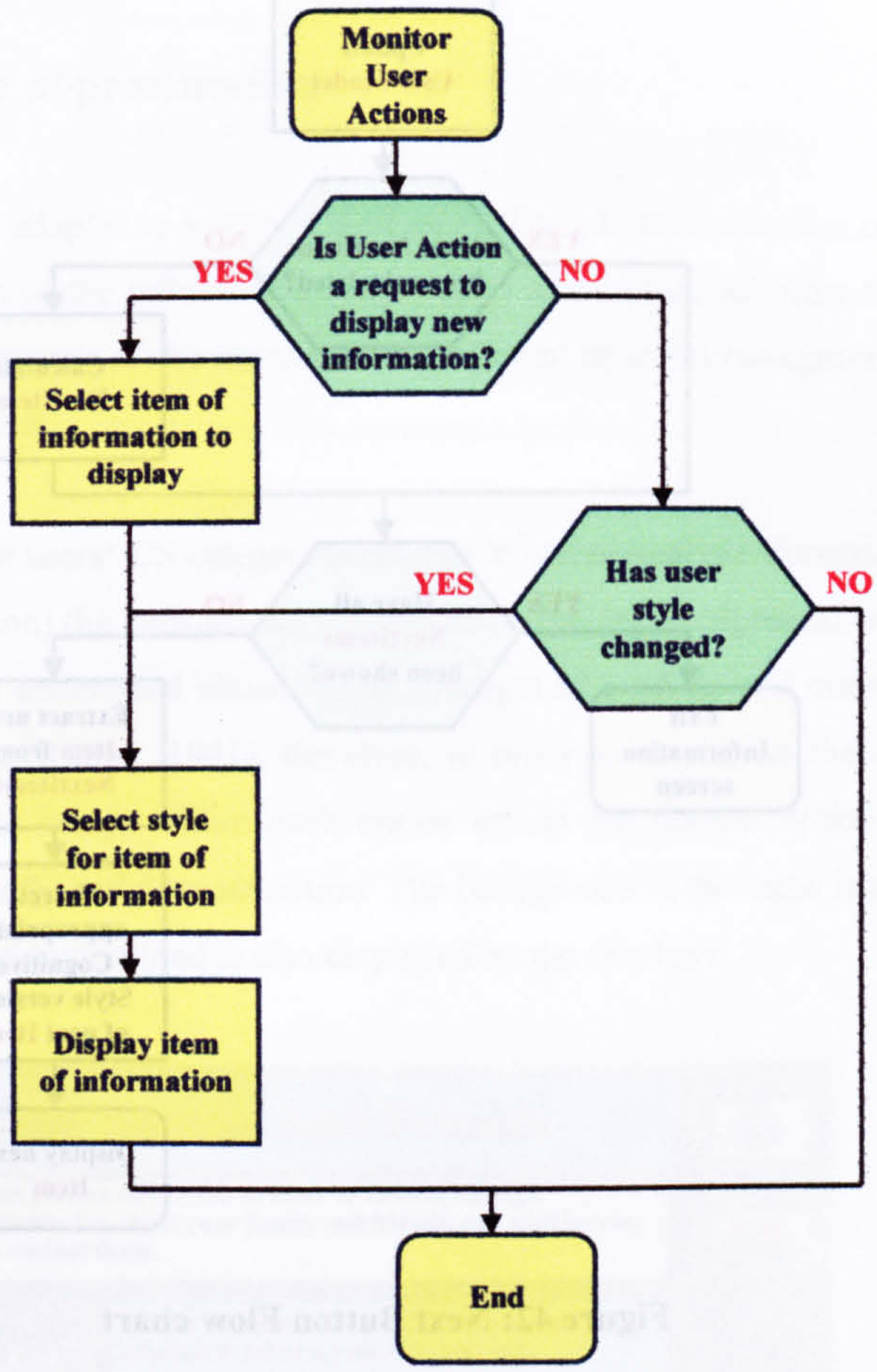


Figure 41: Processes of the Output Manager

The process of selecting information is different depending on whether the user selects a hyperlink or clicks on the *Next* or *Previous* buttons. When a user clicks on a hyperlink the version of the selected *item of information* that matches their CS is presented. When the *Previous* button is chosen the *item of information* that was presented before the current item is shown (listed in the *System usage history* database). When the user clicks on the *Next* button a series of rules are followed to select the *item of information* that matches their goals and their current state of knowledge. The processes that are performed when a user clicks on the *Next* button are shown in figure 42.

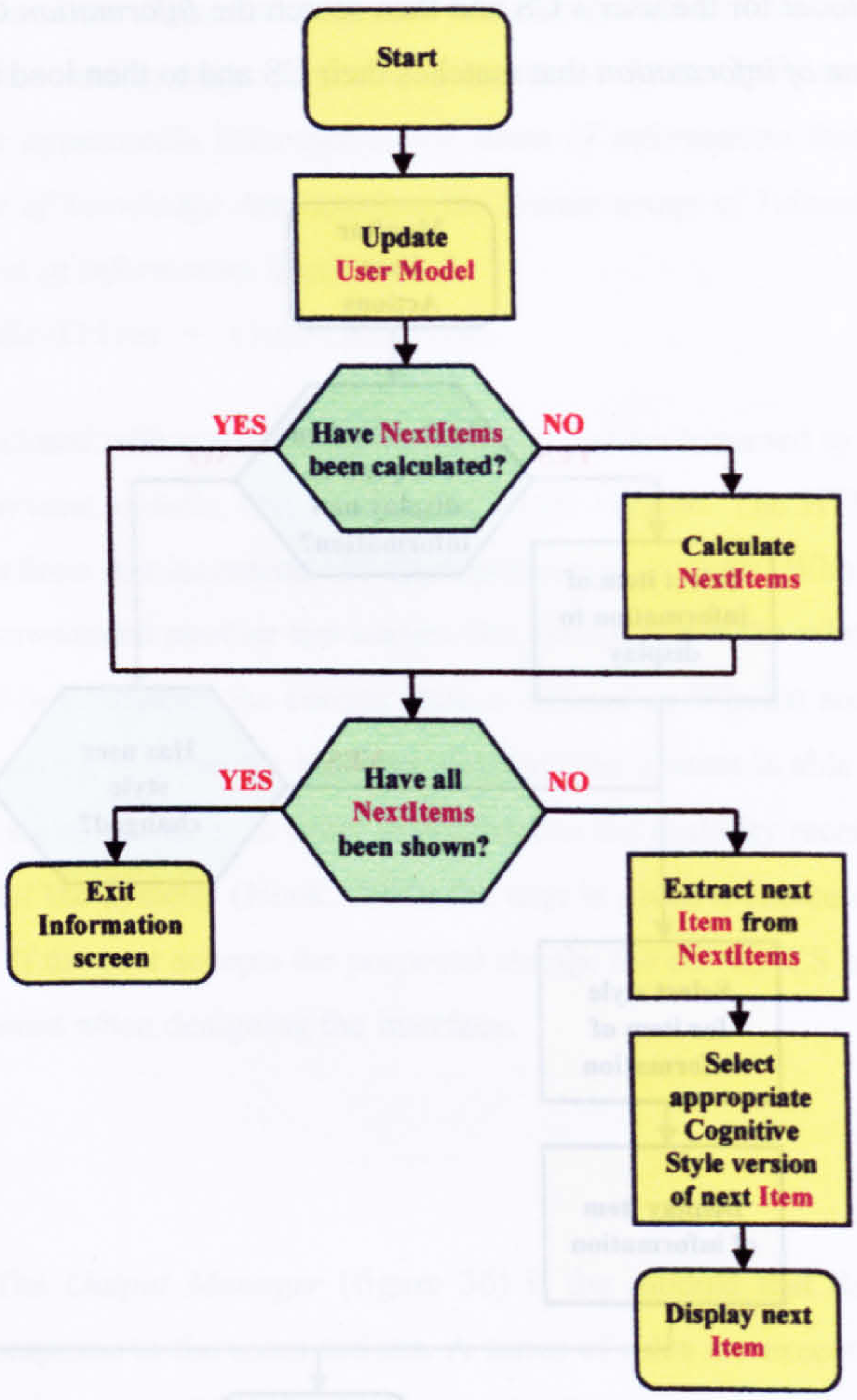


Figure 42: Next Button Flow chart

As shown in figure 42 the first process is updating the *User Model* including the *Current state of knowledge* and *System usage history* (this process is a function of the *Primary User Modeller*, described in section 3.2.1.4). Then a test occurs to determine whether all the *items of information* (named in the *NextItems* list) that are needed to satisfy the user's current *goal* have been displayed. The user's goal is defined when the user starts to browse through the *Information Content*. User goals can be set as the selected subjects in the *General Information* or *Medical Information*. When the *Help* option is selected the *goal* is defined as learning about the part of the system that the user is currently using. This *goal* is saved in the *User Model* database and can be accessed elsewhere in the program by accessing the *User Model* database:

```
GoalToFind = Trim(frmDatabaseInformation.txtStudentModelGoal.Text)
```

When the goal is established a list of all *items of information* that are required to satisfy the goal is compiled from the hierarchy of *subjects*, *topics* and *sub-topics* (stored in the *NextItems* list).

When an *item of information* is viewed it is removed from the *NexrItems* list. If the *NextItems* list is empty then there are no more *items of information* to view and in the case of the *Help* system the user is returned to the part of the system where they selected the *Help* option, or if viewing the *General Information* or *Medical*

Information the users are able to select another subject. If the *NextItems* list is not empty then the next *item of information* is extracted from the *NextItems* list. The CS of the user is accessed from the *User Model* and the version of the selected *item of information* that matches the user's CS is displayed.

3.2.2 Adapting the style of presentation

The style of presentation was adapted to suit the CS of users. The adaptive selection of information described above determines the content of the information displayed to users while adapting the style of presentation determines the background features of the environment. Different styles of background images are displayed depending on the CS of the user.

The *User Model* value for the users' CS category along the Wholist-Analytic dimension is tested. If the user is a Wholist (the first condition) the background (displayed on the *imgBackground* Image control) is chosen as the background. Wholists understand situations or concepts as a whole and consequently may miss the distinction between the parts (Riding, 1991), therefore, in order to emphasise the distinction between the main options the background image within each option reflect the current option. Figure 43 shows the Wholists interface of the *Family and Friends* option. The background is the same image that is displayed on the *Family and Friends* option button (and is also displayed on the title bar).

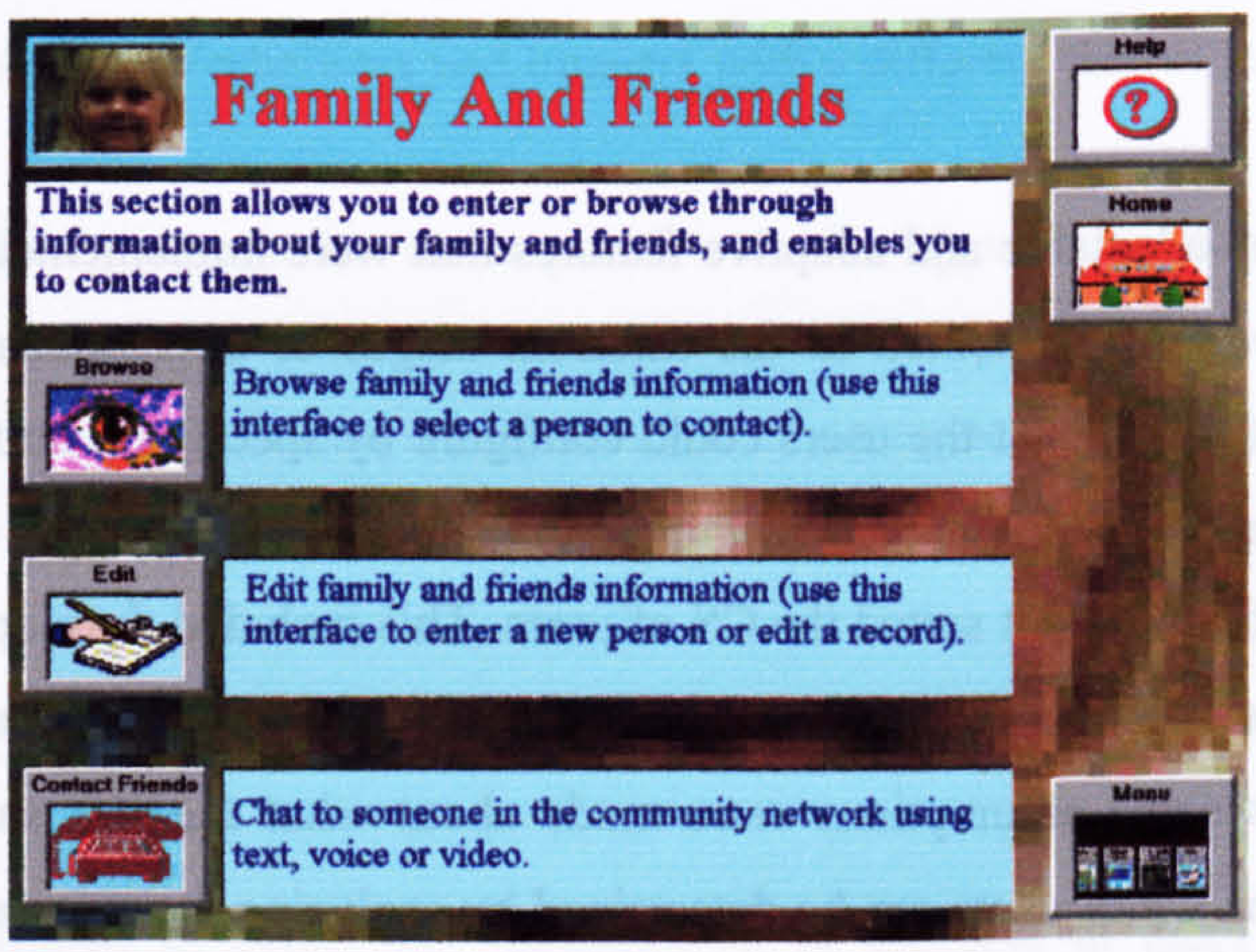


Figure 43: Wholist background for family and friends option

If, however, the user is an Analytic (the "Else" condition) the background remains the same throughout the system. Analytics understand situations or concepts as a collection of parts and consequently may miss the overall context (Riding, 1991), therefore to emphasise that each of the main options are part of the same system the background images are not changed in the different options. Figure 44 shows the Analytic interface for the *Family and Friends* option. The background image not the same as the image used to represent the *Family and Friends* option but is the same image that is displayed for all options and was selected using the rules described in section 3.1.2.1.

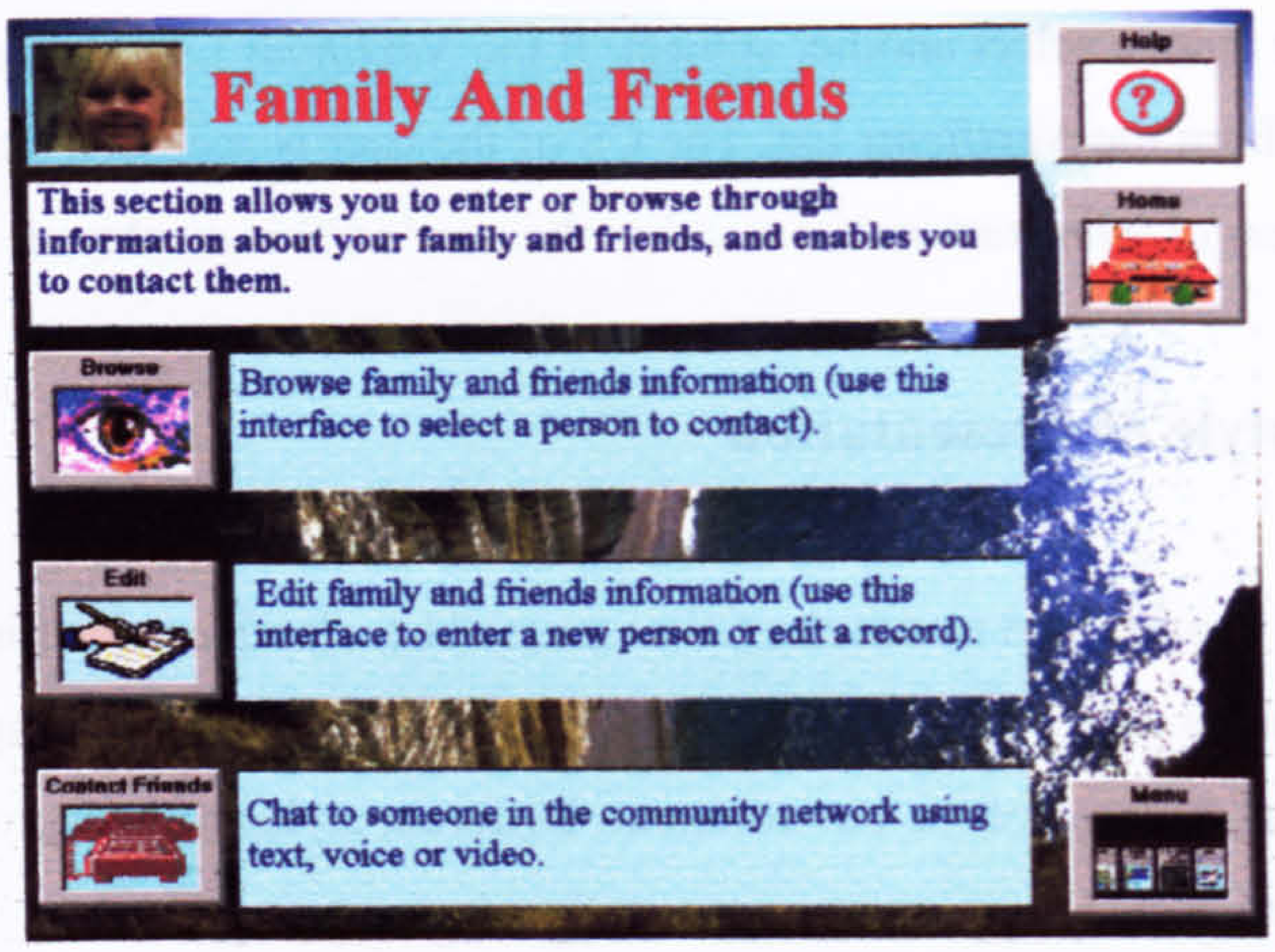


Figure 44: Analytic background for family and friends option

The *Main Option* screen also alters the presentation for Verbalisers and Imagers. The auditory cue that plays when the mouse moves over the options buttons (section 2.2.2.1) is different for Verbalisers and Imagers. Verbalisers are presented with auditory cues that use spoken words to indicate the content of each of the *Main Option* buttons, while Imagers are presented with sound effects that represent the function of the option.

3.3 Conclusion

This chapter described the adaptable and adaptive features that were implemented in the telecare prototype. The different features were implemented in the different stages of development. The first stage was to develop some adaptable features that the users could configure by specifying preferences. The second stage was to adapt the selection of *items of information* to suit the goals and knowledge of the user. The third stage was to develop adaptive features that suited the CS of users. This included developing alternative versions of information that were designed to suit different CSs and to adapt the presentation style of the interface. To implement these features some assumptions were made about what features suited individual users with different CSs, and how the CS of users can be determined by analysing the users actions. These assumptions need to be tested to determine whether groups of users with the same CS receive the expected benefits when interfaces are designed to suit their CS and whether their CS can be determined by analysing their interaction. The next chapter attempts to answer these questions by describing the first in a series of experiments that examine the performance of subjects using different styles of interface.

4 Presenting interfaces to suit the user's cognitive style

This chapter describes an experiment that was set up to examine how cognitive style (CS) affects the performance of individuals in tasks using a multimedia interface. The experiment was designed to test whether CS affects the performance of users in a predictable manner and whether the CS of users can be determined by examining the way they use the system.

4.1 Planning the experiment

The *Telecare Companion* contained some adaptive features that involved presenting different designs of interface or users with different CSs. These development features lead to a number of questions that needed to be answered, including:

- Is the performance of users enhanced by adapting the interface to suit their CS?
- Is it possible to determine the CS of users by monitoring their actions as they use the system?

An experiment was set up to answer these questions. The main aim of the experiment was to determine whether the performance of individuals is improved by adapting the interface in a manner that reflects the way they perceive information, e.g. presenting Wholists and Analytics with information that is structured in a different manner, and presenting Verbalisers and Imagers with a different mix of media.

A secondary aim was to determine whether it was possible to identify a user's CS by monitoring the way they use the system, e.g. determining whether Wholists are more likely to select certain types of link than Analytics and whether Imagers are more likely to click on images rather than text, and vice versa for Verbalisers.

4.2 Method of the experiment

The experiment was designed to assess the performance of subjects in tasks using different styles of interface. For both CS dimensions alternative interfaces were presented that reflected the way information is processed by individuals with different CSs. The CS of subjects was assessed using the CSA test and the performance of subjects in the different CS groups were compared between the different styles of task.

The experiment used a mixed factorial fully crossed 2x2 design with user CS as the between subjects independent variable and presentation style as the within-subjects independent variable. For both dimensions there were four conditions depending on the presentation style and CS of subject (figure 45). The effects on performance of each CS dimension were examined separately. The performance of Wholists were compared to Analytics in both the Wholist and Analytic tasks and the performance of Verbalisers were compared to Imagers in the Verbaliser and Imager tasks.

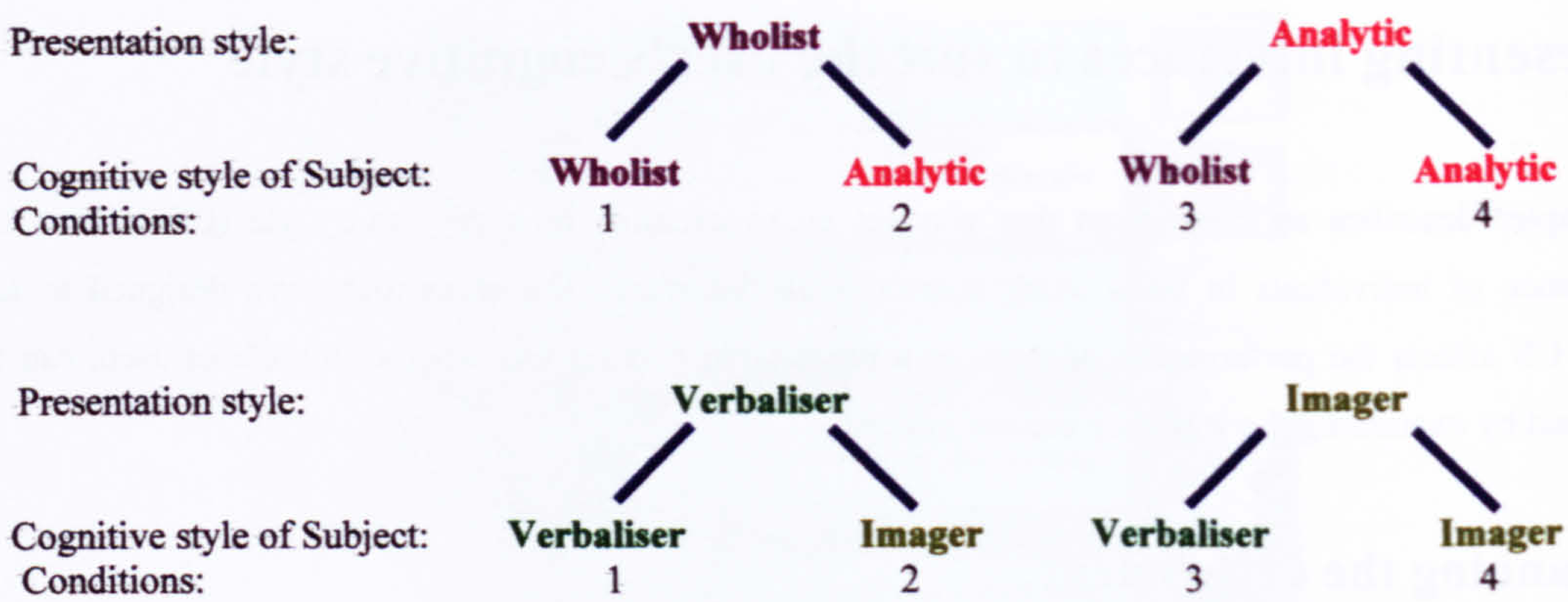


Figure 45: Mixed factorial fully crossed 2 x 2 design

Subjects were asked to perform both versions of each set of tasks. Any effects that may have resulted because of the order which subjects undertook the tasks were counter-balanced by randomising the order (i.e. effects of Wholist subjects that performed the Wholist task first were counter-balanced by the Wholist subjects that performed the Analytic task first and the effects of Verbaliser subjects that performed the Verbaliser task first were counter-balanced by the Verbaliser subjects that performed the Imager task first).

Each task was implemented using VB and used the same screen layout as the *Telecare Companion* system (chapter 2).

4.2.1 The Wholist-Analytic dimension task

The task that was designed to examine the effect of the Wholist-Analytic dimension was to undertake a tutorial on how to measure blood pressure using a sphygmomanometer (Appendix 1). Two versions of the tutorial presentation were prepared, one designed to reflect the way Wholists learn (the W task) and the other designed to reflect the way Analytics learn (the A task). After completing each tutorial the performance of subjects were assessed by a series of twenty multiple-choice questions (Appendix 2).

Wholists store information serially and learn new topics as self-contained units (Riding, 1991). The sequence in which information is presented is important as they recall the information in that sequence. To reflect the way Wholists learn, the W task was presented as a single video clip containing live action, still images and text accompanied by a spoken soundtrack that lasted 4 minutes 44 seconds.

The W task interface provided subjects with a *Play* button to start the presentation, and *Pause*, *Rewind* (skip-back) and *Fast Forward* (skip-forward) buttons (figure 46). It was necessary to provide these option buttons to allow subjects the facility to view the part of the tutorial more than once. The use of the *Rewind* and *Fast Forward* buttons did not alter the sequence that the information was presented but allowed the subjects more control over the flow of information.

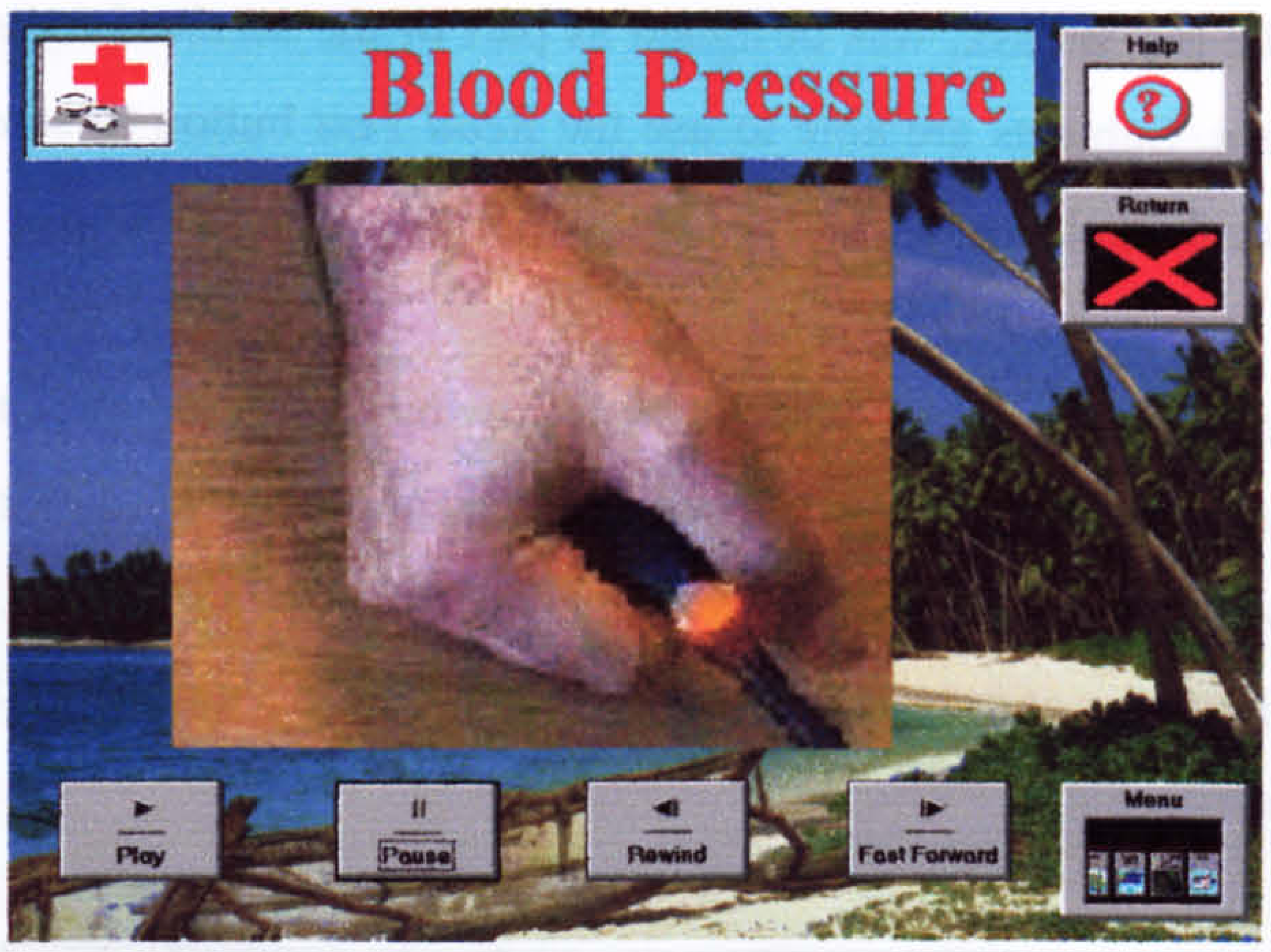


Figure 46: Wholist Task Interface

The W task was designed as part of the *Medical Information* option within the *Telecare Companion* system. As the experiment required the tutorial to be performed as a stand alone task the *Help*, *Return* and *Menu* options were disabled. When the video was completed the system automatically displayed the test interface.

Analytics are more capable of imposing their own structure on learning material and process information in parts, attaching each part to information they already know (Riding, 1991). The A task reflected the way Analytics learn by presenting the same information that was presented in the W task (Appendix 1) in the form of an interactive hypermedia network containing text, images and short video clips. The tutorial is organised as a hierarchy of *items of information* in the same manner as the *General* and *Medical Information* of the *Telecare Companion* system (section 2.2.4.2). The tutorial contained 28 *items of information* consisting of 24 HTML files and 4 AVI files. Each *item of information* was placed in the same *Sub-topic* and the *goal* was set to learn all information contained in the *Sub-topic*.

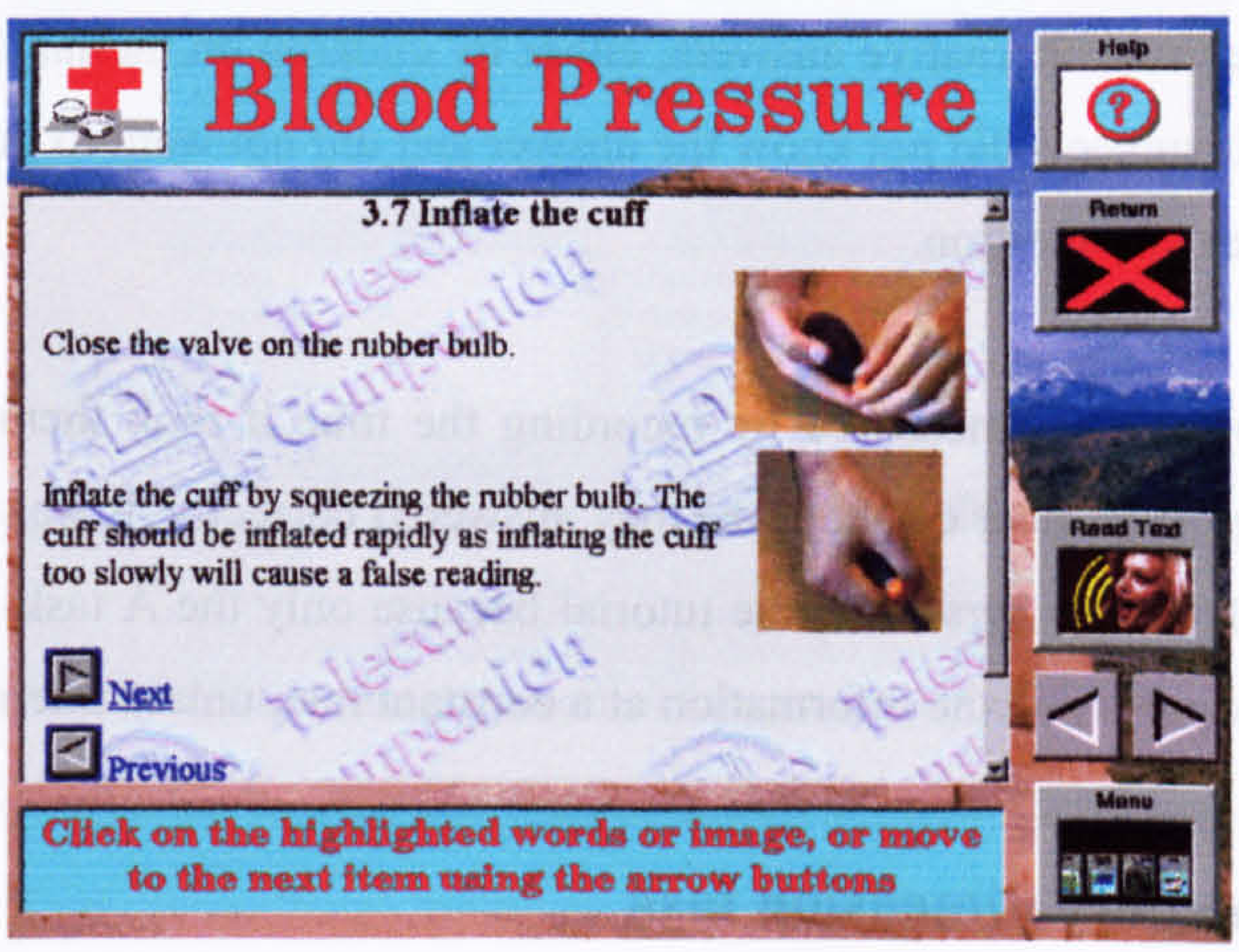


Figure 47: Analytic task interface

The A task (figure 47), like the W task, was designed as part of the *Medical Information* option within the *Telecare Companion* system. Subjects are able to use the *Read Text* button to send all text that is currently displayed to the text-to-speech application.

Subjects are able to control the flow of information by following the hyperlinks underlined in the text or by requesting the system to select which *item of information* to display next by clicking on the *Next* arrow or to review what has already been viewed by clicking on the *Previous* arrow. The *Help*, *Return* and *Menu* options were disabled. When all the *items of information* in the tutorial had been displayed the system automatically displayed the test interface.

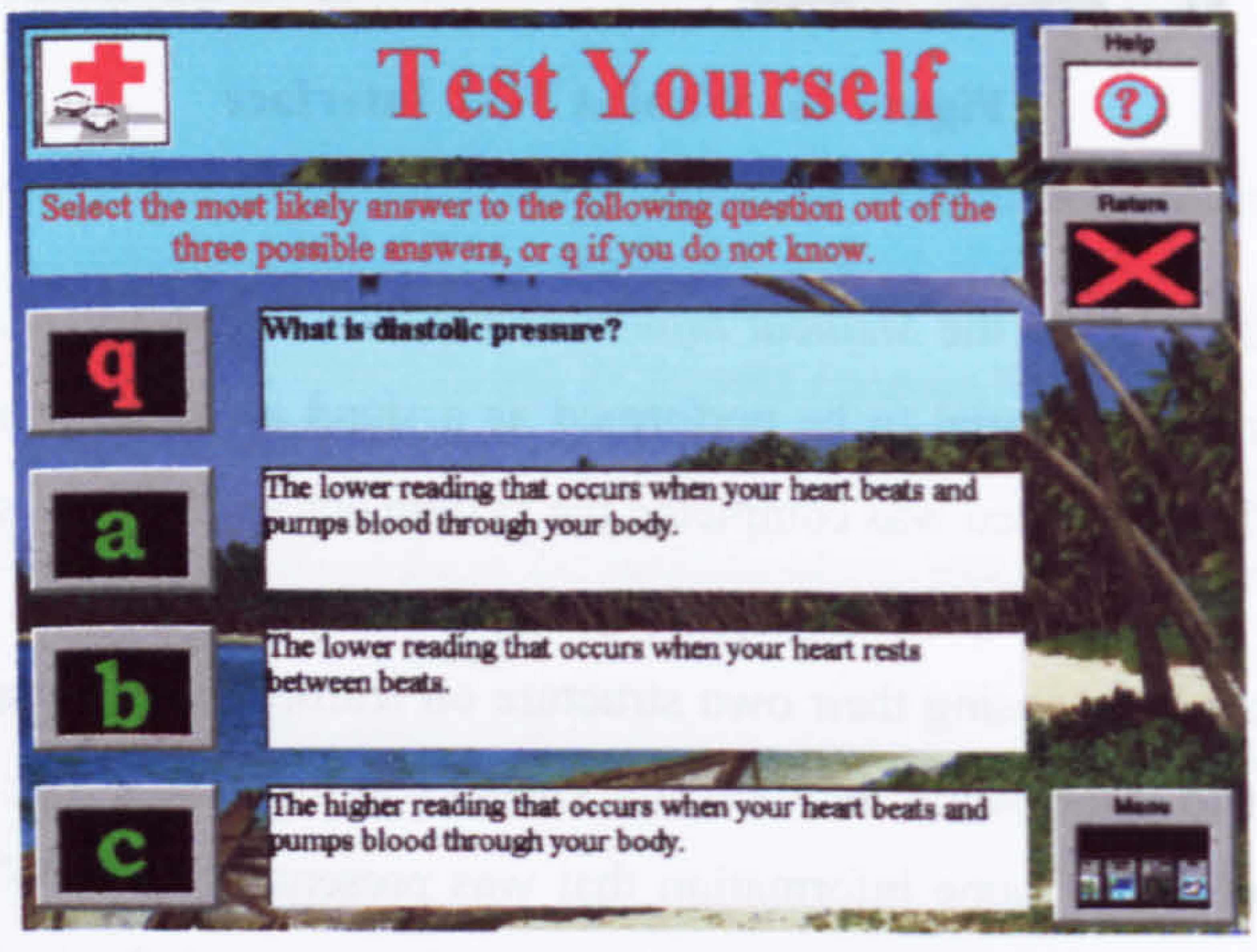


Figure 48: Multiple-choice question test interface

The multiple-choice question test interface (figure 48) was used after both the W and A versions of the tutorial with the same 20 questions (Appendix 2). Individual questions appeared in the top label box with the light blue background and were read aloud by the text-to-speech application. Subjects entered their answers by clicking on one of the three alternative answers, either by clicking on the label itself or on the associated button ("a", "b" or "c"). If subjects did not know the answer and did not want to guess they could click on the "q" button to go on to the next question.

The performance of subjects was measured by recording the time it took them to complete the multiple-choice test and recording the number of questions they answered correctly. It was not appropriate to compare the time it took to complete each version of the tutorial because only the A task interface was controlled by the user while the W task presented the information at a constant rate, unless interrupted by the user.

4.2.2 The Verbal-Imagery dimension task

The task that examined the effect of the VI dimension was to enter two records into the *Family and Friends* database of the *Telecare Companion* system. The difference between the two versions of the task is the amount of text or images used in the interface. Verbalisers are expected to prefer text-based information rather than image-based information while Imagers are expected to prefer image-based information rather than text-based information (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1998). Therefore the Verbaliser interface (the V task) was a text-based interface and the Imager interface (the I task) was more graphical.

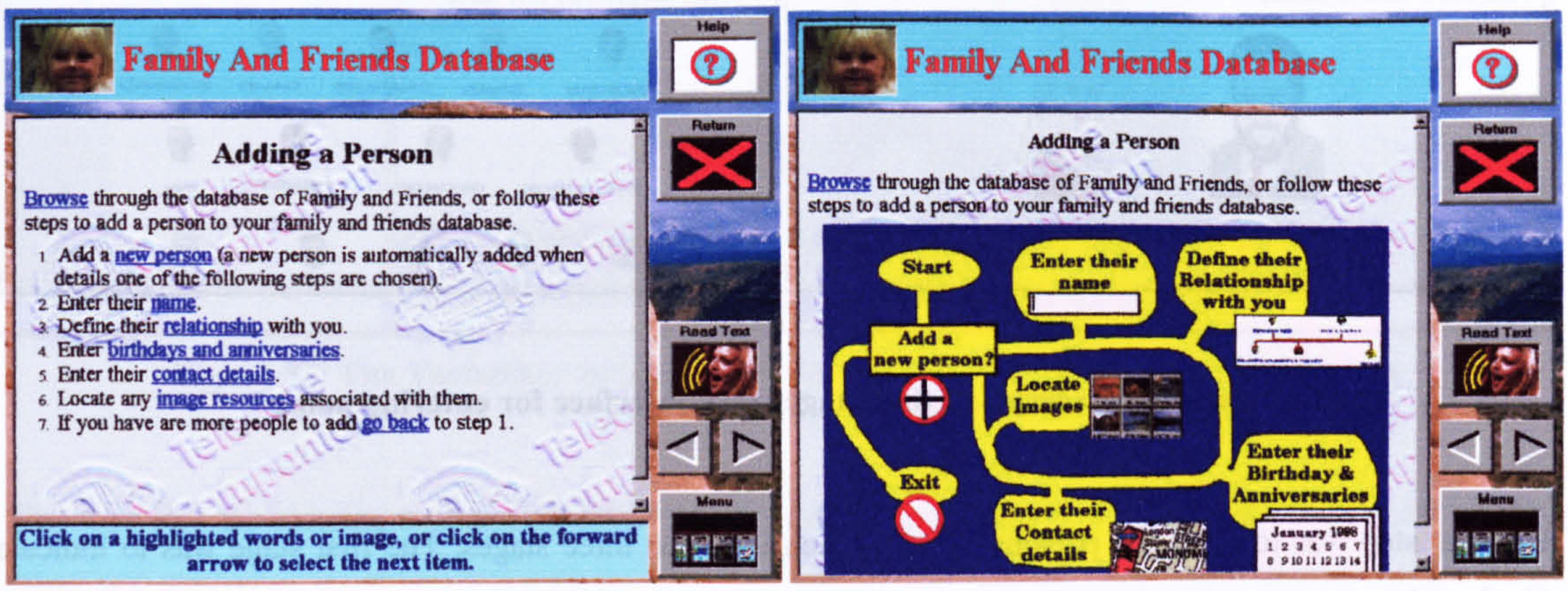


Figure 49: Verbaliser and Imager task interface

Figure 49 shows the menu screens for the V task and the I task that outlines the procedure of entering the details for one record in the *Family and Friends* database. The V task interface (left image figure 49) represents the procedure as a sequential numbered list of steps while the I task interface (right image of figure 49) represents the procedure as a map with a path that can be followed to complete each step. Each step number is displayed on the V task interface while the step image is displayed on the I task interface.

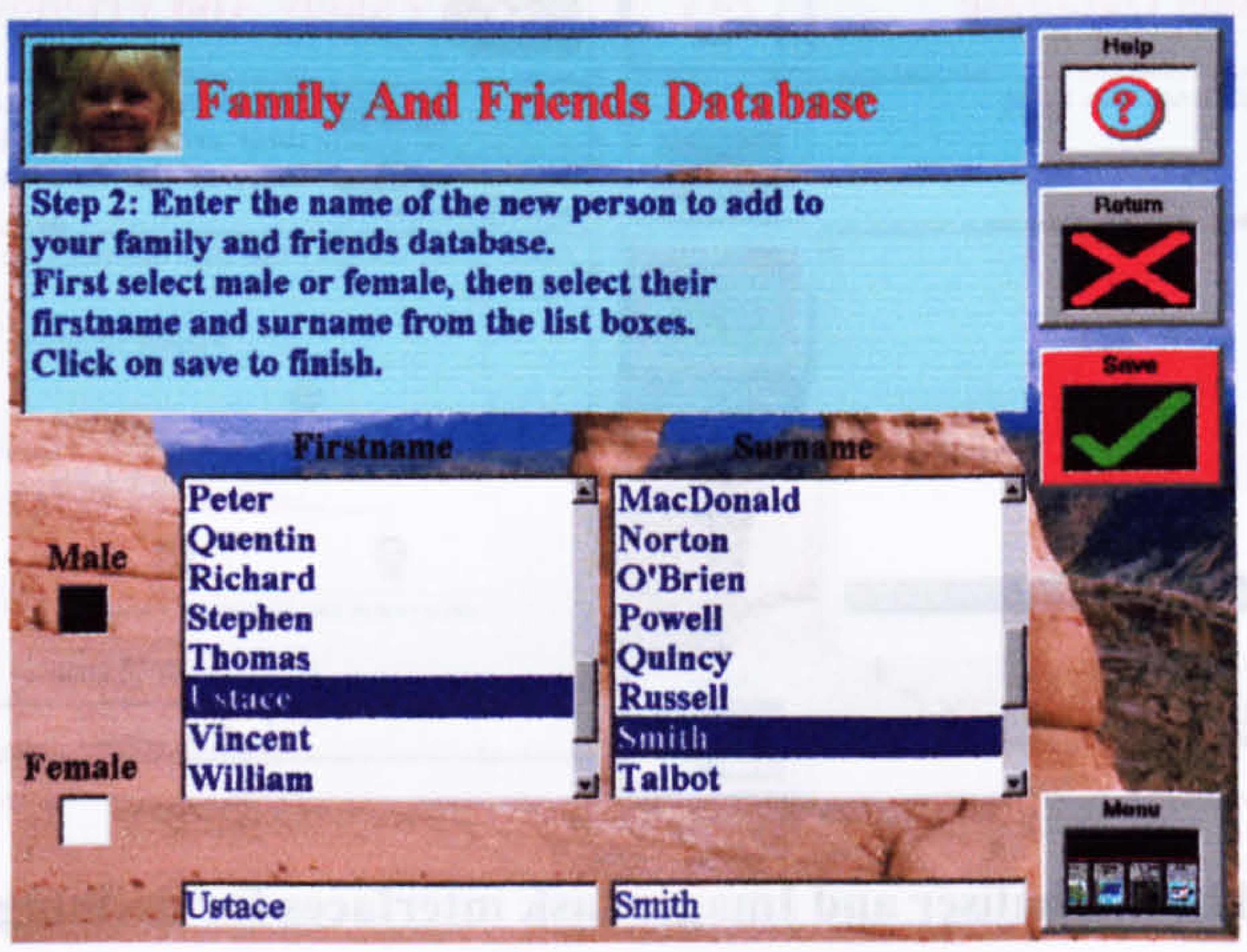


Figure 50: Verbaliser task interface for entering name

One entry in the *Family and Friends* database included the following data: the person's *name* (first name and surname), their *relationship* with the *primary user* (member of family, friend from work, friend from the community network etc.), *birthdays or anniversaries* of the person, their *contact details* (full address, phone and videophone number) and *image resources* (images or videos associated with that person including portraits, holidays, pets etc). The details that subjects were required to enter are shown in Appendix 3.

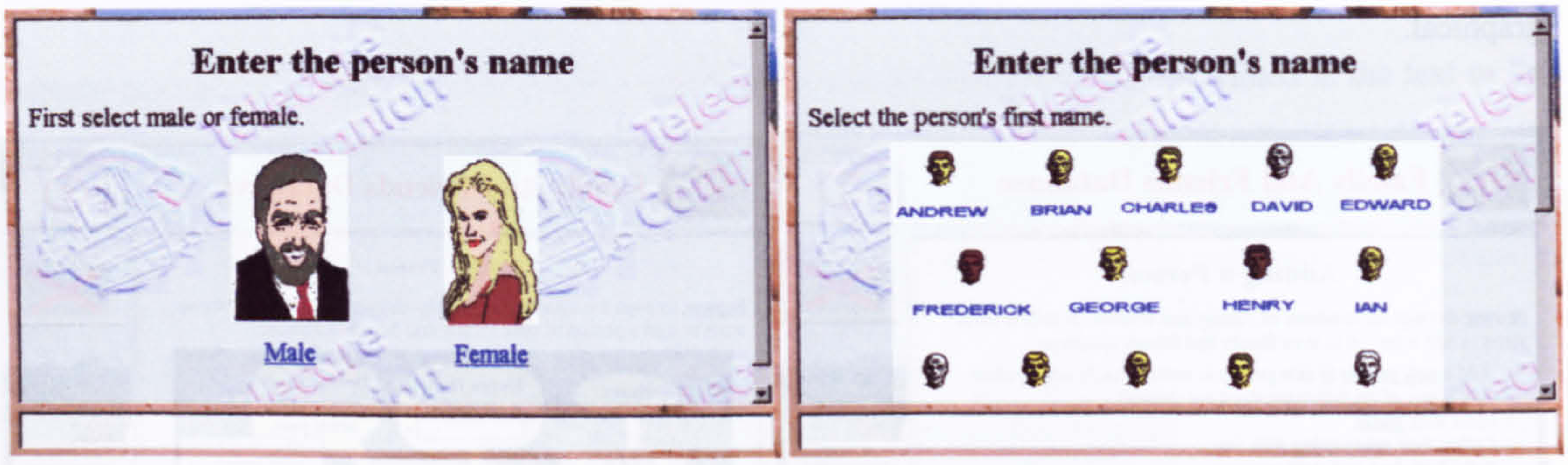


Figure 51: Excerpts of the Imager task interface for entering name

The first step was to enter the persons' name, which involved three stages. The first stage was to indicate whether the person was male or female. The V task requires subjects to select male or female using the check-boxes in the left-hand column (figure 50). This leads to the next stage of selecting the first name and second name from the two sets of list boxes. The I task, however, splits these stages across separate screens. Figure 51 shows excerpts of the screens for entering male or female and selecting names. Subjects first select one of the images representing male or female (left image figure 51) and then select the icons associated with the names and surnames (right image of figure 51). For the purposes of this experiment subjects had a limited number of names to choose from and could not type names using the keyboard.

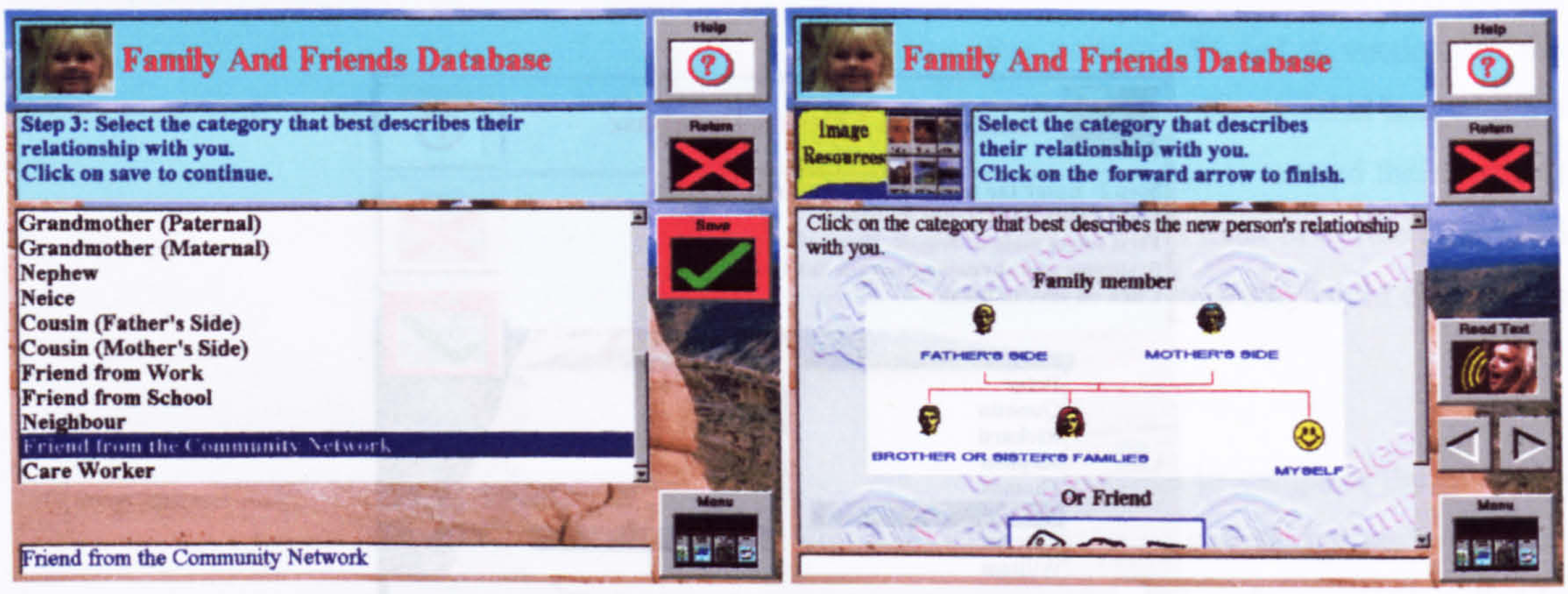


Figure 52: The Verbaliser and Imager task interfaces for defining relationship

The second step was to define their *relationship* with the *primary user*. This could be *family member*, a *friend from work*, *school* or the *community network*. The V task (left image of figure 52) allows subjects to select the appropriate label from the list box. The I task (right image of figure 52) requires subjects to select the appropriate image. To enter a *family member*, subjects select the appropriate person from a depiction of a family tree.

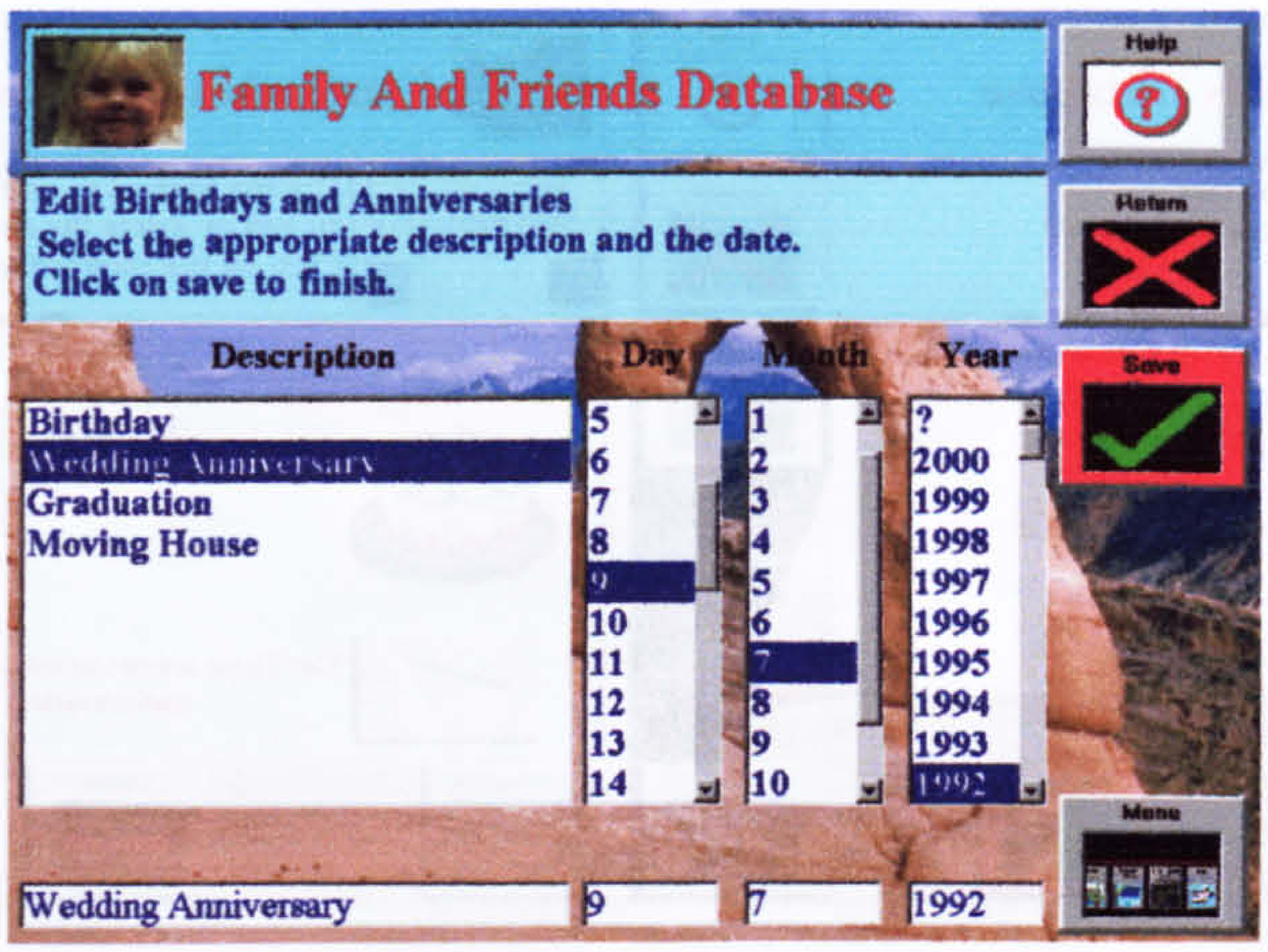


Figure 53: The Verbaliser task interface for entering birthdays and anniversaries

The third step for entering a person into the *Family and Friends* database was to enter the *birthday* or other important *anniversaries* associated with that person. This process involved entering a description (*birthday*, *wedding anniversary*, *graduation* or *moving house*) and then entering the date (*day*, *month* and *year*). The V task interface enables subjects to enter all the information on the same screen by selecting the appropriate label and numbers from the list boxes (figure 53). The same information is entered using the I task interface by first selecting the image that represents the description (left image of figure 54) and then entering the date by stepping through a calendar to the desired year, month and day (right image of figure 54).

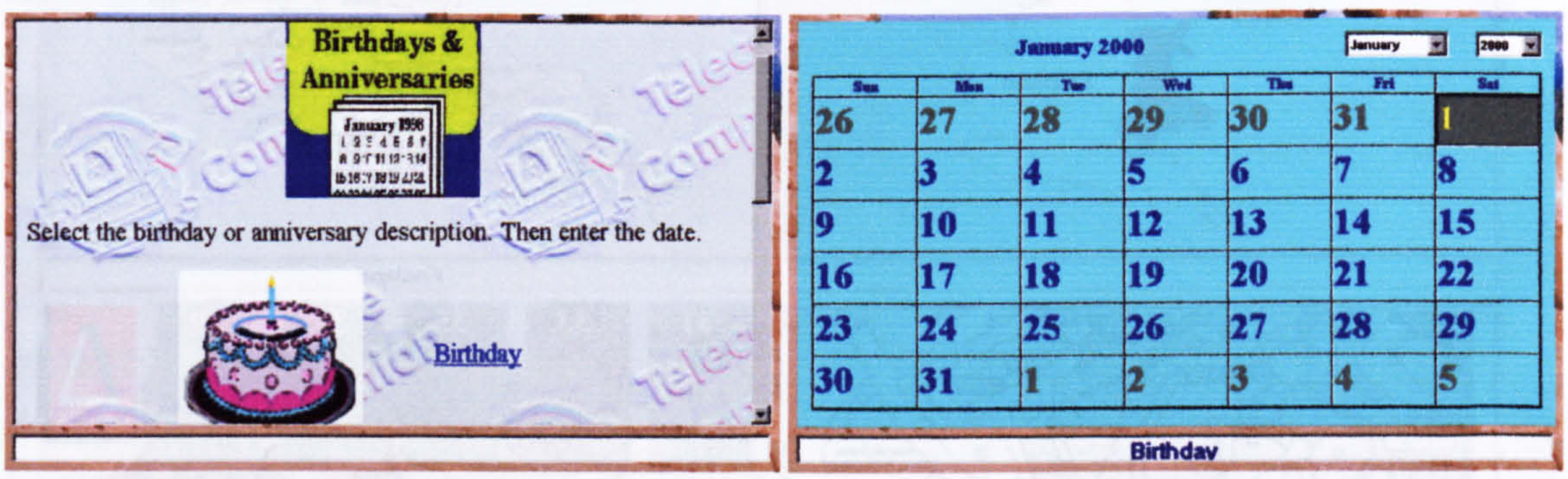


Figure 54: Excerpts of the Imager task interface for entering birthdays and anniversaries

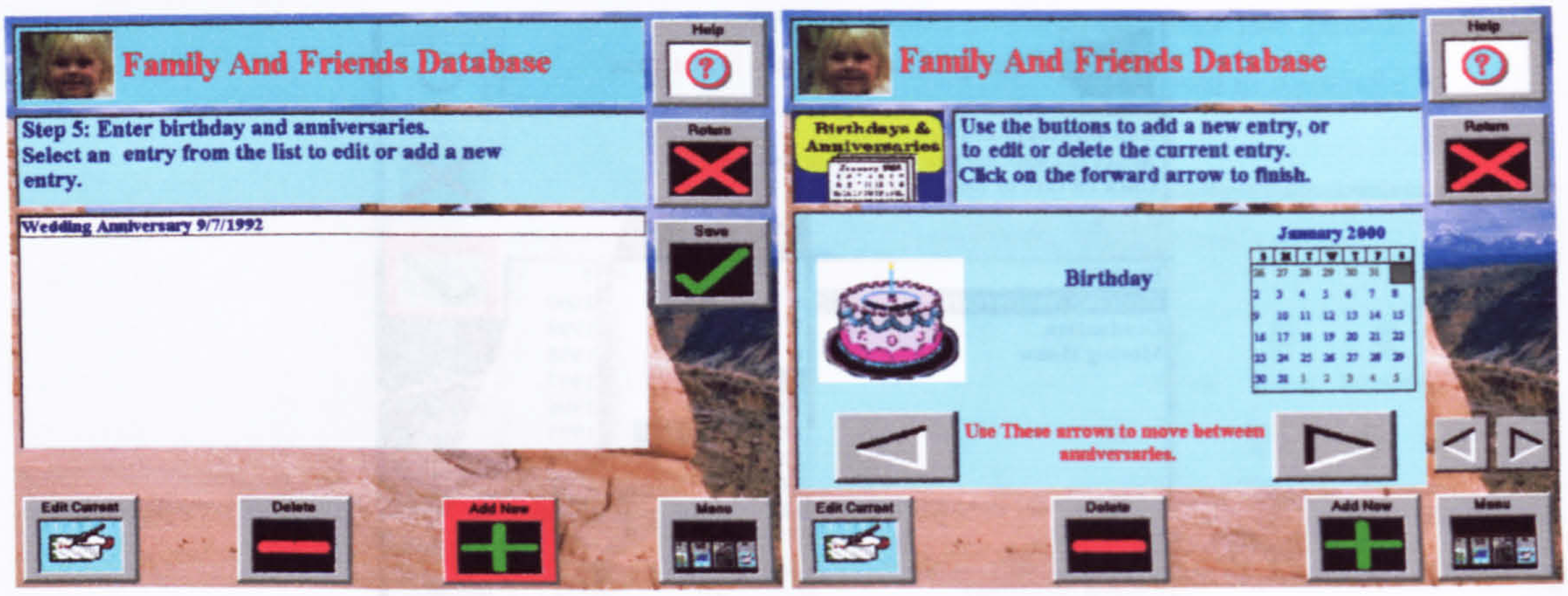


Figure 55: The Verbaliser and Imager task interfaces for browsing birthdays and anniversaries

Birthdays and anniversaries can be edited or deleted by selecting an entry in the list of the V task interface (left image of figure 55) or stepping through all birthday and anniversary entries that are associated with that person in the database using the arrow buttons in the I task interface (right image of figure 55) and then clicking on the appropriate button at the bottom of the screen (*Edit Current* or *Delete*). The *Add New* button (with a plus symbol) is used to add another entry.

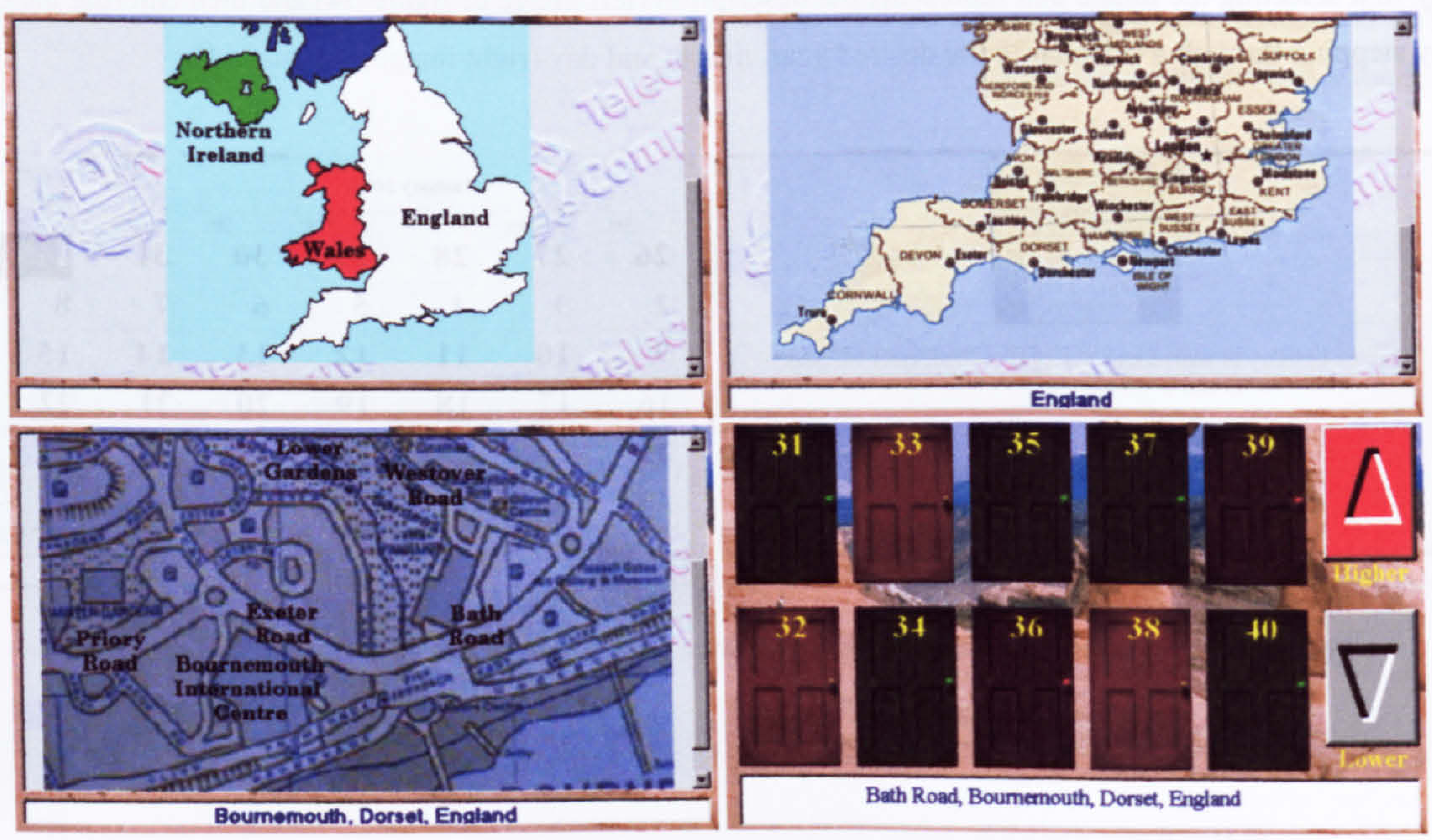


Figure 56: Excerpts of the Imager task interfaces for entering Address

The fourth step is to enter the person's *contact details*. This involves entering their address, e-mail address, telephone and videophone numbers. In the V task the address is built up by selecting labels from a series of list boxes for *country*, *county*, *town*, *street* and *house number*. The address is built up in a similar manner in the I task interface except the elements of the address are selected by clicking on maps rather than list boxes. Figure 56 shows excerpts from the screens used to enter *country* (top left image), *county* (top right image), and *street* (bottom left image). The *house number* is entered by clicking on the appropriate door (bottom right image of figure 56). Only ten doors are visible at one time but others can be viewed by clicking on the *Higher* or *Lower* arrows.

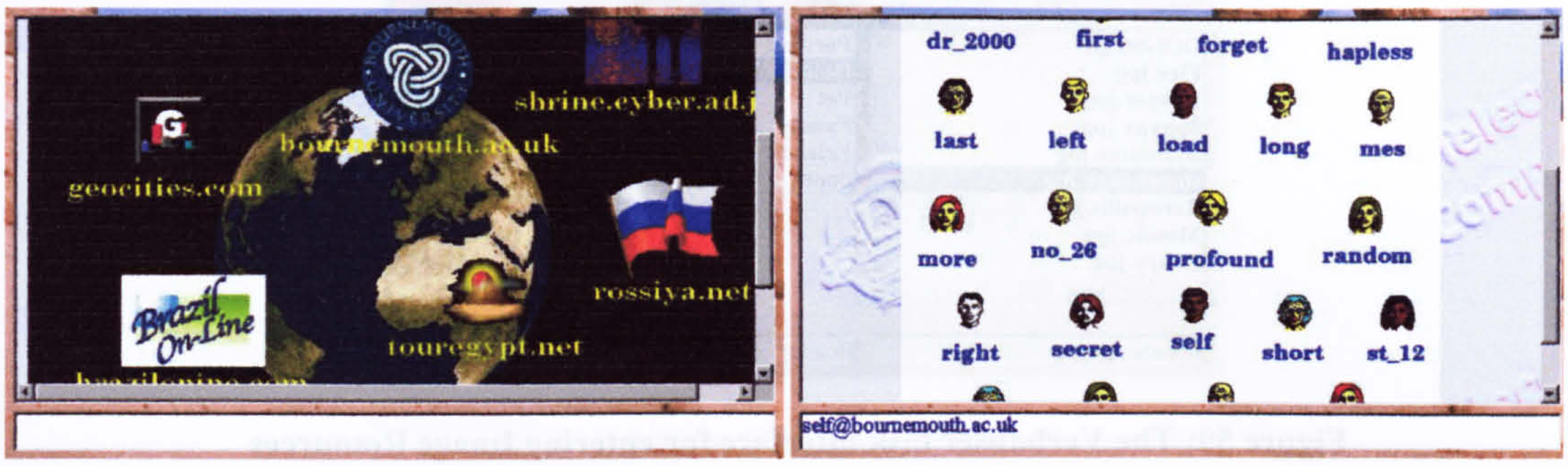


Figure 57: Excerpts of the Imager task interface for entering E-Mail Address

To enter the e-mail address subjects have to select the e-mail provider and the user name. Using the V task interface both elements are entered by subjects selecting the appropriate label from list boxes. Using the I task interface subjects first select the logo of the e-mail provider represented by a globe with the companies located by their geographical position (left image figure 57). Secondly, subjects select the user name by clicking on the icon associated with the appropriate user name (right image figure 57). For the purposes of this experiment a limited number of email providers and user-names were presented and subjects did not need to type information using the keyboard.

Figure 58: The Verbaliser and Imager task interfaces for entering telephone number

Both the telephone and videophone numbers are entered by subjects clicking on the appropriate digits. The V task presents the digits in a list box (left image figure 58), while the I task displays a keypad of numbered buttons (right image figure 58).

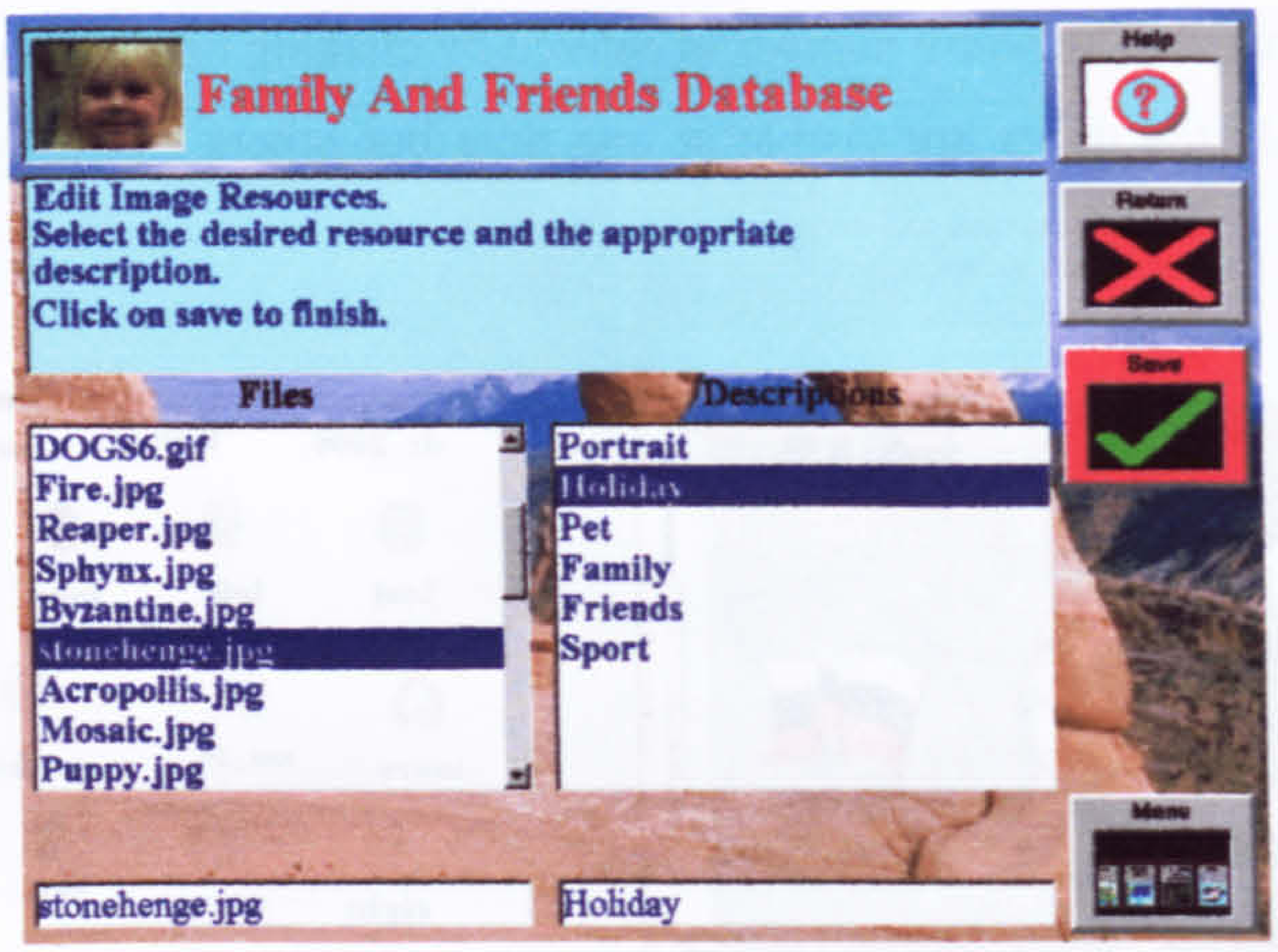


Figure 59: The Verbaliser task interface for entering Image Resources

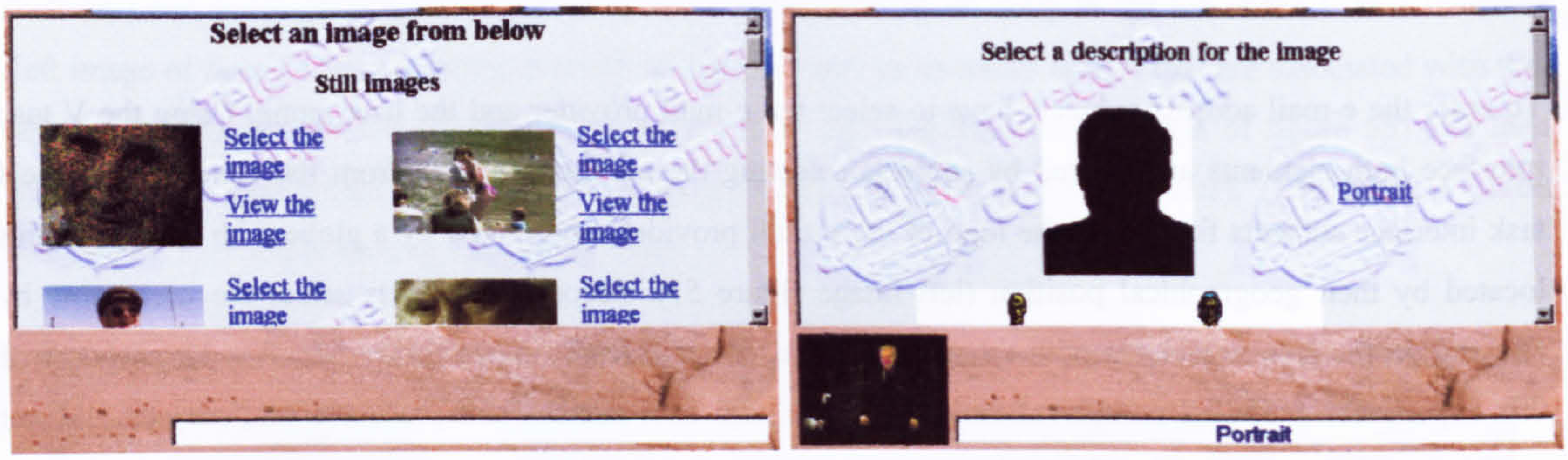


Figure 60: Excerpts of the Imager task interface for entering Image Resources

The last step is to identify the image resources associated with the person. This involves locating the file (which could be an image or video clip) and selecting a description (which could be *Portrait*, *Holiday*, *Family*, *Friends* or *Sport*). In the V task subjects select the file name and description from the list boxes (figure 59). The image can be viewed by double-clicking on the file name. The I task does not list the file name but displays thumb-nail images that can be selected (left image figure 60). A second screen displayed a number of images to represent the description (right image figure 60). For the purposes of this experiment there are a predefined collection of images and videos and subjects cannot add files to this collection.

Individual images can be viewed using the interface shown in figure 61 by selecting images either from the list in the V task interface or from the thumb-nail images displayed by the I task interface. Video clips can be viewed using an interface similar to the W task (figure 46).

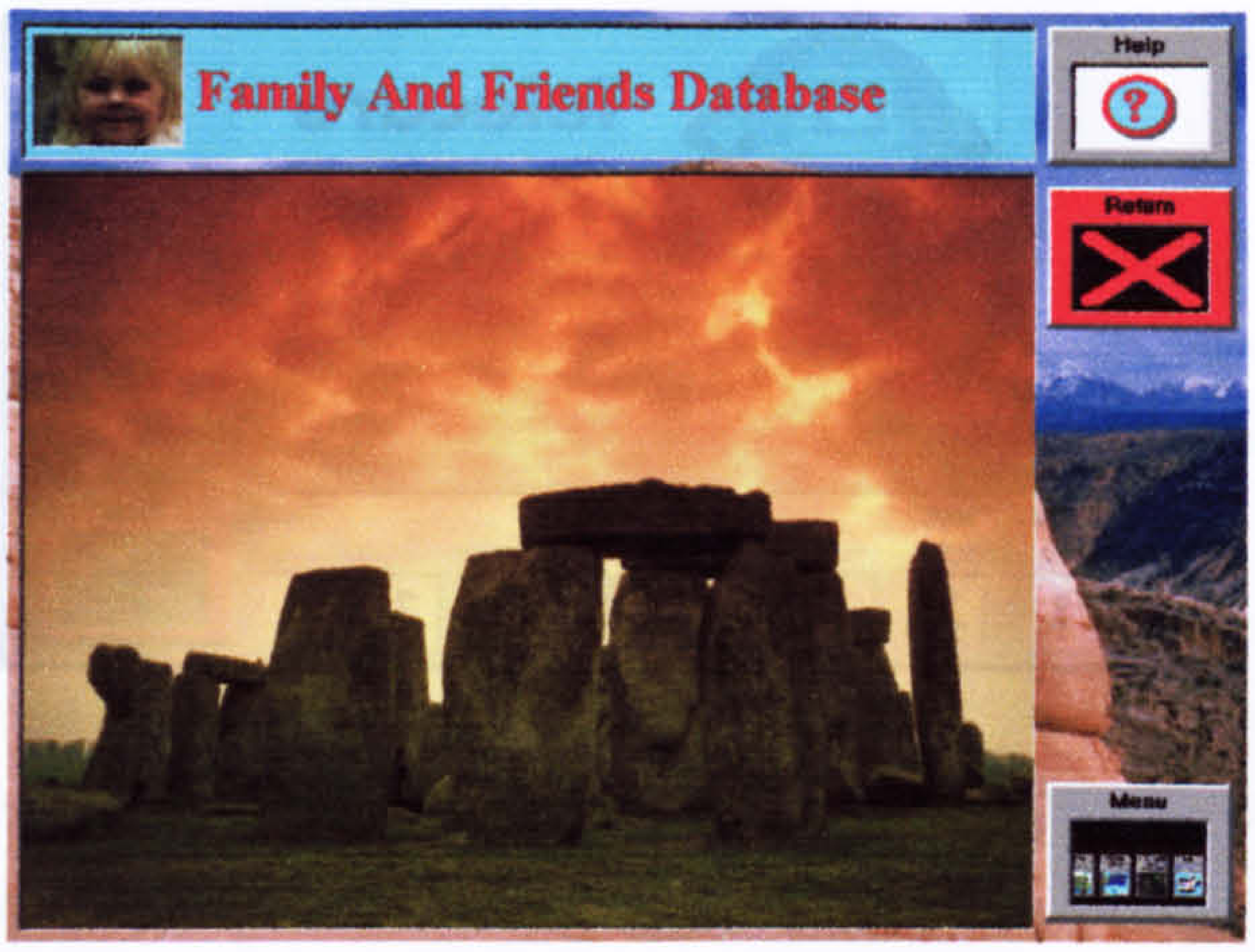


Figure 61: Interface for viewing Image Resources

Figure 62: The Verbaliser and Imager task interfaces for entry confirmation

Before the person's details are saved in the database there is one final screen that displays the entry details and asks the subjects to confirm that the details are correct. The V task interface (left image figure 62) displays the details as text. The I task interface (right image figure 62) superimposes the details over the map used in the menu screen (right image figure 49). To change any of the details subjects had to click on the desired section and the system will display the appropriate interface to enable subject to enter the correct details. When the details have been re-entered the system returns the subject back to the confirmation screen.

4.2.3 Conditions of the experiment

24 subjects were selected randomly from the staff and students at Bournemouth University and asked to perform all the tasks using a multimedia PC. When starting the experiment each subject entered their name and their mode using the subject details screen (figure 63).

Figure 63: Subjects Details screen

There were 8 different modes which dictated the order in which the computer presented the tasks (table 2). The modes were evenly distributed among the subjects (three subjects per mode). This ensured that the number of subjects that performed the W task first were counter-balanced by the subjects that performed the A task first. The mode was assigned randomly without prior knowledge of the subjects' CS.

Mode	1st Task	2nd Task	3rd Task	4th Task
1	Wholist	Analytic	Verbaliser	Imager
2	Wholist	Analytic	Imager	Verbaliser
3	Analytic	Wholist	Verbaliser	Imager
4	Analytic	Wholist	Imager	Verbaliser
5	Verbaliser	Imager	Wholist	Analytic
6	Verbaliser	Imager	Analytic	Wholist
7	Imager	Verbaliser	Wholist	Analytic
8	Imager	Verbaliser	Analytic	Wholist

Table 2: Experiment Mode

Subjects took between 40 minutes and one hour to complete all four tasks. Their CSs were then assessed using the CSA after they had completed all the experiment tasks.

In both sets of experiments the system recorded all the user activity in a database of user actions (including key strokes, mouse clicks, the time, what the user clicked on, what the command is for, which screen is currently being displayed, and which *item of information* is currently being displayed). For example, when a subject selects a hyperlink the following code is called from within the *HTML_Error* sub procedure:

```
frmDatabaseActions.SaveAction "HTML", newLink
```

frmDatabaseAction is the name of the VB Form in which the *SaveAction* sub procedure is defined. "HTML" is the action label (the action of clicking on a hyperlink). *NewLink* is the name of the hyperlink (the name of the requested *item of information*). Hyperlinks are set to the names of *items of information* and not the name of a file. The VB HTML control attempts to load the *item of information* but as this is not the name of an HTML file the *HTML_Error* sub procedure is activated. The appropriate file to load is calculated and called from the error sub procedure using the same rules that are described in chapter 3 except there are no alternatives to the Analytic version of the file. In this manner hyperlinks are not tied to single URLs but links to *Next* and *Previous* items can be included which have to be calculated each time they are selected. Further, hyperlinks to non-HTML files such as AVI files could be called which are not displayed using the VB HTML control but with a VB Multimedia control.

The system also records whether the subject clicked on an image or on a text label. For example, when a subject clicks on the *Read Text* command button the following code is executed:

```
frmDatabaseActions.SaveAction "Speak - Imager", currentItem
```

The action records both that the *Read Text* command button was selected ("Speak") and that the subject clicked on the command button image ("Imager"). It was assumed that Imagers would be more likely to click on the image section of buttons.

When the subject clicks on the area surrounding the image the following code is executed:

```
frmDatabaseActions.SaveAction "Speak - Verbaliser", currentItem
```

The action records both that the *Read Text* command button was selected ("Speak") and that the subject clicked on the area surrounding the image ("Verbaliser"). It was assumed that Verbalisers would be more likely to click on the text area of a button rather than the image. This information was recorded to test whether Imagers were more inclined to click on images than text and whether Verbalisers were more inclined to click on text than images.

4.2.4 How performance was measured and analysed

There were two main measures of performance that were recorded in this experiment. The first measure was the amount of information that users could absorb from the system. This was measured by testing the users' knowledge in a series of questions or by testing the ability of subjects to perform tasks. The second measure of performance was the speed in which users are able to use the system. This was measured by recording the amount of time that users spent performing the tasks.

There is usually a trade off between the two measures of performance as users who have absorbed a lot of information may have taken a long time to perform the task while users who perform a task quickly may have absorbed little information. A better indicator of overall performance is a measure that combines the two measures. A performance ratio (PR) can be obtained by dividing the score achieved in tests by the time taken:

$$Performance\,Ratio = \frac{Scores}{Duration}$$

For the Wholist-Analytic tasks a PR was calculated for each subject by dividing the percentage of questions subjects answered correctly (mean score) by the mean duration that subjects took to answer one question (total time divided by the number of questions). For the Verbal-Imagery tasks a PR was derived from a calculation of score (the percentage of data entered correctly) divided by the average time it took to enter one data item. The calculation of duration contained an adjustment for each missing piece of data. The time penalty was calculated from the average time it took subjects to enter one piece of information.

For subjects to achieve a high PR they have to score high in a short duration. Where all subjects scored similarly the difference in the performance of subjects is magnified by dividing the scores by the duration. However, where there is a wider variation between the scores of subjects the effect may be lessened by dividing the scores by the duration.

The performance of subjects was examined by testing the hypothesis that subjects in each CS group would perform better using the style of interface that was designed to suit their CS than the opposite style of interface. There were two types of comparison that were carried out:

1. The relative performance of the different CS groups:
   - The performance of Wholists compared to Analytics in the W task
   - The performance of Wholists compared to Analytics in the A task
   - The performance of Verbalisers compared to Imagers in the V task
   - The performance of Verbalisers compared to Imagers in the I task
2. Performance between the different styles of task:
   - The performance of Wholists between the W task and the A task
   - The performance of Analytics between the W task and the A task
   - The performance of Verbalisers between the V task and the I task
   - The performance of Imagers between the V task and the I task

For both types of comparison the mean PRs of each CS group were compared against each other using a number of procedures to test the statistical significance of the observed differences (Howell, 1995; Microsoft, 1997b; SPSS, 1999):

1. The relative performance of the different CS groups:
   - **One-way Analysis of Variance** (One-way ANOVA, calculated using the SPSS General Linear Model Univariate procedure). Used to test whether there are any significant differences between the mean PRs achieved by each CS group within each task. CS is found to have a significant effect on the performance of subjects where the *between-subjects* significance value is less than 0.05. CS has a marginally significant effect on performance where the significance values are between 0.05 and 0.10. Where no significant or marginal effect is detected the hypothesis is rejected and the conclusion is that CS has not affected performance.
   - **Eta squared** (the *Magnitude of Effect*). Used to assess the degree to which variability in the performance of subject can be attributed to their CS classification. The values range from 0.00, which indicates there is no link, to 1.00 which indicates there is a strong link.
   - The **observed power**. This figure calculates the probability that the conclusion drawn from the calculation of significance is correct e.g. incorrectly rejecting a false hypothesis (a type II error). The values range from 0.00, which indicates that there is a greater probability of a type II error

occurring, to 1.00 which indicates that there is a greater probability that the conclusion based on the significance figure is correct.

- **Independent-samples t-tests.** Used to test the difference between the mean PRs of two different groups of subjects. The range of significant values is the same as the on-way ANOVA procedure.
- The post hoc **Tukey** test (an option provided by the SPSS package within the one-way ANOVA procedure). This was performed to calculate whether the mean PRs of the CS quadrants were significantly different from each other. The range of significant values is the same as the on-way ANOVA procedure.

2. Performance between the different styles of task:
   - **Paired-samples t-test.** Used to test the difference between the mean PRs of each group of subjects between the different types of task. The range of significant values is the same as the on-way ANOVA procedure.

3. Between the CS groups and style of task:
   - **Two-way Analysis of Variance** (Two-way ANOVA, calculated using the SPSS General Linear Model Repeated Measures procedure). Used to test whether any difference in performance of one task that is attributed to CS was matched by a corresponding effect in the opposite style of task (e.g. if the relative performance of Wholists and Analytics in the W task was matched by the opposite relative performance in the A task). The range of significant values is the same as the one-way ANOVA procedure.

4.3 Results of the experiment

This section examines whether the performance of subjects supported the hypothesis that individuals perform better using a style of interface that was designed to suit their CS, and whether the CS of users can be accurately determined by analysing their actions as they operate the system.

4.3.1 Cognitive style of subjects

In order to simplify the analysis of the results of the experiments subjects are divided into two groups along each cognitive style dimension (Wholist or Analytic, and Verbaliser or Imager) rather than the three groups classified by the CSA test (Wholists-Intermediate-Analytic, and Verbaliser-Bimodal-Imager). This allowed the performance of subjects in opposite halves of each dimension to be directly compared using ANOVA calculations and t-tests. The manner of dividing subjects follows the method used in experiments carried out by the author of the CSA test (Riding & Sadler-Smith, 1992; Riding & Read, 1996). Subjects in the middle groups are divided at the mid-point of each CS dimension and placed in the nearest group. To ensure that there was little distortion in the assessment of performance due to the inclusion of the subjects from the middle groups the results of the ANOVA calculations performed with all subjects were compared against the results of the ANOVA calculations performed without the subjects from the middle groups. There were no differences in the results of the calculations performed with or without the subjects from the middle groups. Where significant or marginally significant interactions were detected between CS and performance for all subjects, corresponding interactions were detected in the calculations performed without the subjects from the middle groups.

Dividing subjects at the mid-point of the intermediate section of the WA dimension and the mid point of the Bimodal section of the VI created four groups consisting of Wholists, Analytics, Verbalisers and Imagers. When the two dimensions are considered together a grid with four CS quadrants are created; Wholist/Verbalisers, Wholist/Imagers, Analytic/Verbalisers and Analytic/Imagers. Subjects were plotted by their CSA rating for both dimensions (figure 64).

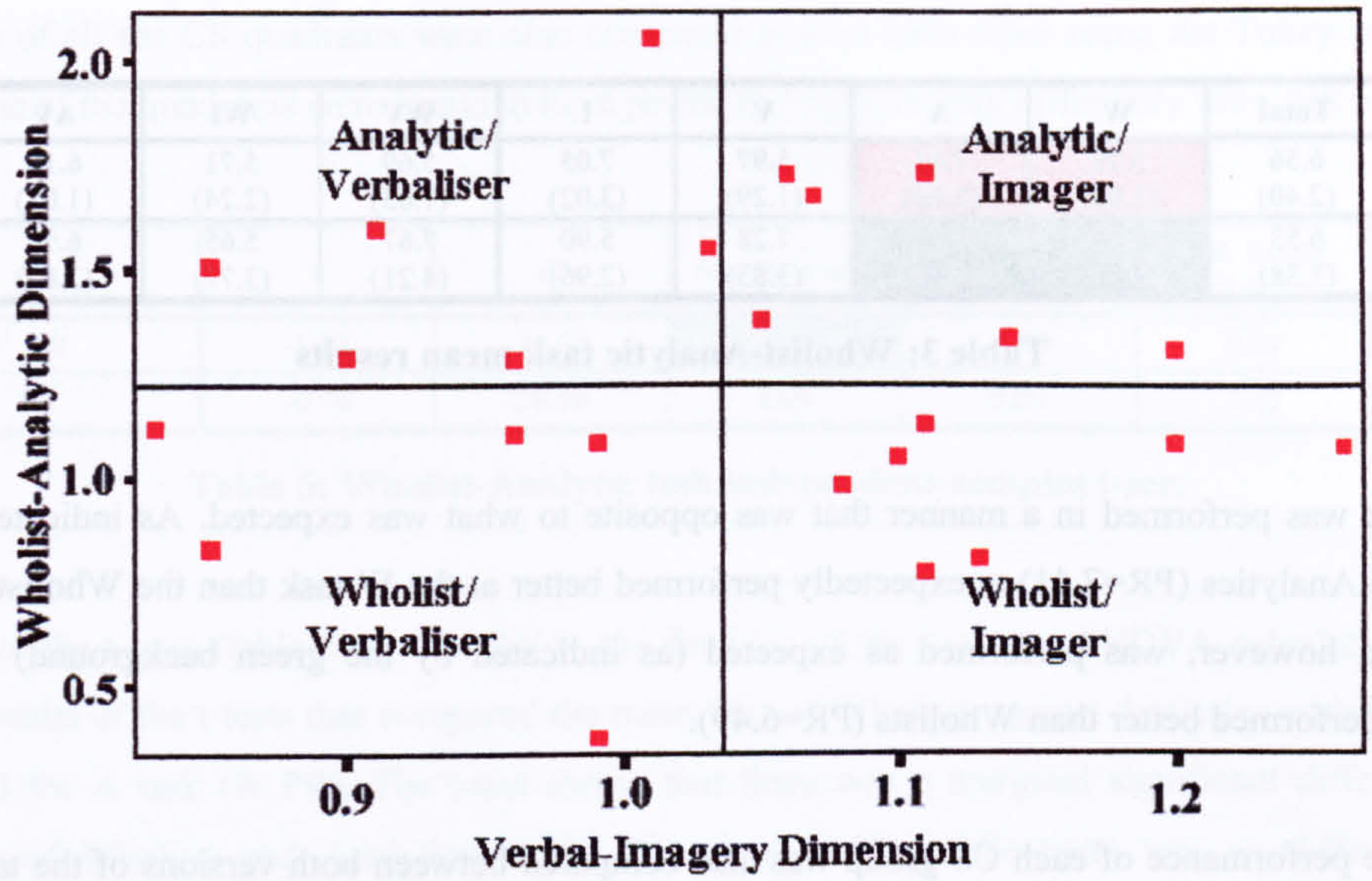


Figure 64: Scatter-graph of subjects cognitive style classification

As shown in figure 64, there was an even spread of subjects. There were equal numbers of Wholists (12) and Analytics (12), and almost an equal numbers of Verbalisers (11) and Imagers (13). Dividing the subjects into the quadrants there were 5 Wholist/Verbalisers, 7 Wholist/Imagers, 6 Analytic/Verbalisers and 6 Analytic/Imagers.

4.3.2 Results of the Wholist-Analytic tasks

This section presents the results of subjects in the WA tasks. As indicated by the icon the performance of Wholists was compared against Analytics to test whether the relative performance was as expected. Firstly, it was expected that Wholists would perform the W task better than Analytics and that Analytics would perform the A task better than Wholists. Secondly it was expected that Wholists would perform the W task better than the A task, and Analytics would perform the A task better than the W task.

4.3.2.1 Mean performance in the Wholist-Analytic tasks

Table 3 shows the mean PRs achieved by subjects in the multiple-choice tests in the W task (W_PR) and the A task (A_PR). The results of subjects are divided into each of the CS groups (Total=all subjects regardless of CS, W=Wholist, A=Analytic, V=Verbaliser, I=Imager, WV=Wholist/Verbaliser, WI=Wholist/Imager, AV=Analytic/Verbaliser, AI=Analytic/Imager). The standard deviation for each group is shown in brackets.

Measure	Total	W	A	V	I	WV	WI	AV	AI
W_PR	6.56 (2.40)	5.70 (1.93)	7.41 (2.60)	5.97 (1.29)	7.05 (3.02)	5.69 (1.65)	5.71 (2.24)	6.19 (1.01)	8.62 (3.21)
A_PR	6.53 (3.38)	6.49 (3.91)	6.57 (2.93)	7.28 (3.83)	5.90 (2.96)	7.67 (4.21)	5.65 (3.77)	6.95 (3.85)	6.19 (1.93)

Table 3: Wholist-Analytic task mean results

The W task was performed in a manner that was opposite to what was expected. As indicated by the red background Analytics (PR=7.41) unexpectedly performed better at the W task than the Wholists (PR=5.70). The A task, however, was performed as expected (as indicated by the green background) as Analytics (PR=6.57) performed better than Wholists (PR=6.49).

The relative performance of each CS group was also compared between both versions of the task. Wholists unexpectedly achieved higher PRs for the A task (PR=6.49) than the W task (PR=5.70). Analytics, unexpectedly, achieved higher PRs for the W task (PR=7.41) than for the A task (PR=6.57).

Conclusions cannot be drawn from the mean performance of the CS groups without testing whether the performance of each group was significantly different. The next three sections present the results of the procedures that were performed to test whether the relative performance between the CS groups were as expected or not.

4.3.2.2 The relative performance of the different cognitive style groups

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
W_PR	3.51	0.08	0.15	0.43	1.81	0.19	0.08	0.25
A_PR	0.00	0.95	0.00	0.05	0.92	0.35	0.04	0.15

Table 4: Wholist-Analytic task one-way ANOVA

Table 4 shows the results of the one-way ANOVA between-subjects effects. For both the W task (W_PR) and the A task (A_PR) the mean PRs of Wholists were compared against Analytics (WA) and the mean PRs of Verbalisers were compared against Imagers (VI). The columns show the F statistic, the level of significance (Sig.), the Eta Squared and Observed Power values.

The one-way ANOVA calculations assess whether the differences in performance between subjects were due to their CS. Table 3 showed that Analytics achieved a higher PR than Wholists in the W task and table 4 shows that the PRs of Wholists and Analytics were marginally different (p=0.08, Eta Squared=0.15, Observed Power=0.43). None of the other combinations of measures showed that CS had a significant effect on performance (p>0.05). However the Eta squared and Observed Power values for all measures were low and so the significance statistic is not conclusive, and effects may exist that were not detected. The performance of all the CS quadrants were also compared against each other using the Tukey post-hoc test, however none of the quadrants were found to have performed significantly differently from any of the others.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
W_PR	-1.82	20.30	0.08	-1.70	0.94
A_PR	-0.06	20.40	0.96	0.00	1.41

Table 5: Wholist-Analytic task independent-samples t-test

The results of the t-tests (table 5) are similar to the findings of the one-way ANOVA calculations. Table 5 shows the results of the t-tests that compared the mean PRs of Wholists against Analytics within the W task (W_PR) and the A task (A_PR). The t-test shows that there was a marginal significant difference in the performance of Wholists and Analytics in the W task (p=0.08), while there was no difference in the performance of the A task.

4.3.2.3 Performance between the different styles of task

Pairs	Total	W	A	V	I	WV	WI	AV	AI
W_PR * A_PR	0.98	0.55	0.50	0.34	0.32	0.42	0.97	0.68	0.17

Table 6: Wholist-Analytic task paired-samples t-test

Table 6 shows the results of the t-tests for related samples comparing the performance of each CS group between the W task and the A task. No significant or marginally significant differences were detected for any of the CS groups.

4.3.2.4 Performance between the cognitive style groups and style of task

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
W_PR * A_PR	0.93	0.35	0.05	0.15	0.01	0.92	0.00	0.05

Table 7: Wholist-Analytic task two-way ANOVA

Table 7 shows the results of the two-way ANOVA between-subjects effects. The PRs of Wholists were compared to Analytics (WA) and the PRs of Verbalisers were compared to Imagers (VI) in the W task (W_PR) and the A task (A_PR). The one-way ANOVA between-subjects effects calculations revealed a marginally significant difference in the performance of Wholists and Analytics in the W task (table 4), but this was not matched by a similar difference in the performance of the A task and so no effect was detected in the two-way ANOVA (table 7).

4.3.2.5 Effects of the order of performance of the Wholist-Analytic tasks

Few differences in performance were found between Wholists and Analytics when examining their overall results. This may be because the differences in the performance of subjects who performed the W task first were counter-balanced by the differences in the performance of subjects who performed the A task first. To assess the effects caused by the order in which subjects performed the tasks the performance of the first and second time they undertook the tasks were examined separately. It was expected that subjects who performed the task that matched their CS first would perform better than subjects who performed the opposite style of task. Similarly it was expected that there would be a greater increase in the PRs of the subjects who performed the task that suited their CS second, than the subjects who performed the opposite style of task.

Measure	Cognitive Style of subjects	N	Mean PR
FIRST TASK	Wholist	7	4.90 (1.47)
	Analytic	8	8.31 (2.67)
DIFFERENCE BETWEEN FIRST AND SECOND TASK	Wholist	7	+3.84 (3.03)
	Analytic	8	-3.24 (2.26)

Table 8: Mean results of subjects who performed the Wholist task first

The first set of rows (FIRST TASK) of table 8 show the mean PRs (and standard deviation in brackets) of Wholists and Analytics who undertook the W task first. The second set of rows (DIFFERENCE BETWEEN FIRST AND SECOND TASK) show the difference in performance of Wholists and Analytics between the W task and the A task. The N column shows the number of subjects in each CS group (7 Wholists and 8 Analytics). As indicated by the red backgrounds the results were not as expected. Analytics (PR=8.31) performed the W task better than Wholists (PR1=4.90) and the improvement in performance of Wholists (PR=+3.84) was greater than Analytics (PR=-3.24) after performing the A task.

Measure	Cognitive Style of subjects	N	Mean PR
FIRST TASK	Wholist	5	3.34 (1.00)
	Analytic	4	9.59 (2.22)
DIFFERENCE BETWEEN FIRST AND SECOND TASK	Wholist	5	+3.48 (1.18)
	Analytic	4	-3.99 (2.10)

Table 9: Mean results of subjects who performed the Analytic task first

Table 9 show the mean PRs and standard deviation (in brackets) of the Wholists and Analytics who undertook the A task (FIRST TASK) first and the difference in performance between the A task and the W task (DIFFERENCE BETWEEN FIRST AND SECOND TASK). The N column shows the number of subjects in each CS group (5 Wholists and 4 Analytics). The yellow background indicates the results were as expected. Analytics (PR=9.59) performed the A task better than Wholists (PR=3.34) in the A task, and the improvement in performance of Wholists (PR=+3.48) was greater than Analytics (PR=-3.99) after the W task.

	W (W Task 1) * A (W Task 1)	W (A Task 1) * A (A Task 1)	W (W Task 1) * W (A Task 1)	A (A Task 1) * A (W Task 1)
FIRST TASK	0.01	0.00	0.07	0.43
DIFFERENCE BETWEEN FIRST AND SECOND TASK	0.00	0.00	0.81	0.60

Table 10: Wholist and Analytic effects of order independent-samples t-test

Table 10 shows the results of the independent-samples t-tests comparing the mean PRs between:

- Wholists who performed W task first against Analytics who performed W task first (W (W Task 1) * A (W Task 1))
- Wholists who performed A task first against Analytics who performed A task first (W (A Task 1) * A (A Task 1))
- Wholists who performed the W task first against Wholists who performed the A task first (W (W Task 1) * W (A Task 1))
- Analytics who performed the A task first against Analytics who performed the W task first (A (A Task 1) * A (W Task 1))

The yellow backgrounds indicate where the performance of the two sets of subjects were significantly different ($p<0.05$), while the green background indicates where the performance of the two sets of subjects were marginally different ($p>0.05$ and <0.10). The white backgrounds indicate where the performance of the two sets of subjects were not significantly different ($p>0.10$).

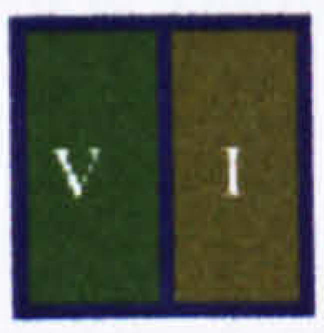
It was expected that Wholists who were presented with the W task first would perform better than Analytics. However performance was opposite to the expectation. Wholists (PR=4.90, table 8) achieved lower PRs than Analytics (PR=8.31, table 8) and the t-tests show that the performance of the two CS groups were significantly different ($p=0.01$, table 10). Similarly it was expected that the difference in performance after the A task was performed would show a greater improvement by Analytics than by Wholists. Again the actual performance was opposite to the expectation. The increase in performance after A task was greater for Wholists (PR=+3.84, table 8) than Analytics (PR=-3.24, table 8) and the performance of the two CS groups were significantly different ($p=0.00$, table 10).

For the subjects who were presented with the A task first it was expected that Analytics would perform better than Wholists. The relative performance of Wholists and Analytics was as expected. Analytics (PR=9.59, table 9) achieved higher PRs than Wholists (PR=3.34, table 9) and the performance of the two CS groups were significantly different ($p=0.00$, table 10). Similarly it was expected that the difference in performance after the W task was performed would show a greater improvement by Wholists than by Analytics. Again, the relative performance of Wholists and Analytics was as expected. The increase in performance after W task was greater for Wholists (PR=+3.48, table 9) than Analytics (PR=-3.99, table 9) and the t-tests show that the performance of the two CS groups were significantly different (p=0.00, table 10).

It was expected that the Wholists who were presented with the W task first would perform better than the Wholists who were presented with the A task first. The t-tests show that the performance of the Wholists who were presented with the W task first were marginally different from the Wholists who were presented with the A task first (p=0.07, table 10) and the PRs show that the relative performance was as expected. Wholists who were presented with the W task first (PR=4.90, table 8) achieved higher PRs than Wholists who were presented with the A task first (PR=3.34, table 9). Similarly it was expected that the difference in performance after the second task was performed would show a greater improvement by the Wholists who performed the W task second. The t-tests show that there was no significant difference in the performance of Wholists between the first and second tasks whether they performed the W task or A task second (p=0.81, table 10).

It was expected that the Analytics who were presented with the A task first would perform better than the Analytics who were presented with the W task first. The t-tests show that there was no significant difference in the performance of Analytics whether they performed the W task or A task first (p=0.43, table 10). Similarly, there was no significant difference in the performance of Analytics between the first and second tasks whether they performed the W task or A task second (p=0.60, table 10).

4.3.3 Results of the Verbaliser-Imager tasks



This section presents the results of subjects in the VI tasks. As indicated by the icon the performance of Verbalisers were compared against Imagers to test whether the relative performance was as expected. Firstly it was expected that Verbalisers would perform the V task better than Imagers and that Imagers would perform the I task better than Verbalisers. Secondly, it was expected that Verbalisers would perform the V task better than the I task and Imagers would perform the I task better than the V task.

4.3.3.1 Mean performance in the Verbaliser-Imager tasks

Table 11 shows the mean PRs achieved by subjects in the V task (V_PR) and the I task (I_PR). The results of subjects are divided into each of the CS groups. The standard deviation for each group is shown in brackets.

Measure	Total	W	A	V	I	WV	WI	AV	AI
V_PR	5.33 (2.69)	4.91 (2.82)	5.75 (2.61)	6.17 (2.59)	4.63 (2.67)	5.19 (3.10)	4.71 (2.84)	6.99 (1.98)	4.52 (2.72)
I_PR	3.97 (1.97)	3.27 (2.15)	4.67 (1.55)	4.45 (1.60)	3.57 (2.22)	3.66 (2.02)	3.00 (2.36)	5.10 (0.85)	4.24 (2.04)

Table 11: Verbaliser-Imager task mean results

As expected (indicated by the green background) Verbalisers (PR=6.17) performed the V task better than Imagers (PR=4.63). However, as indicated by the red background Verbalisers (PR=4.45) unexpectedly performed the I task better than Imagers (PR=3.57).

When comparing the relative performance between both versions of the task Verbalisers, performed the V task (PR=6.17) better than the I task (PR=4.45) as expected, while Imagers unexpectedly performed the V task (PR=4.63) better than the I task (PR=3.57).

4.3.3.2 The relative performance of the different cognitive style groups

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
V_PR	0.53	0.48	0.03	0.11	1.78	0.12	0.08	0.25
I_PR	2.86	0.11	0.13	0.36	0.94	0.34	0.05	0.15

Table 12: Verbaliser-Imager task one-way ANOVA

Table 12 shows the results of the one-way ANOVA between-subjects effects calculations. For both the V task (V_PR) and the I task (I_PR) tasks the mean PRs of Verbalisers were compared to Imagers (VI) and the mean PRs of Wholists were compared to Analytics (WA). None of the of the calculations showed that CS had a significant effect on performance ($p>0.05$). Similarly the Tukey post-hoc tests did not find any significant differences in the performance of the CS quadrants.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
V_PR	-0.76	22.00	0.46	--0.84	1.11
I_PR	-1.82	22.00	0.83	-1.39	0.77

Table 13: Verbaliser-Imager task independent-samples t-test

The results of the t-tests (table 13) also found no differences in performance between the Verbalisers and Imagers in the V or I tasks.

4.3.3.3 Performance between the different styles of task

Pairs	Total	W	A	V	I	WV	WI	AV	AI
V_PR * I_PR	0.00	0.01	0.03	0.03	0.02	0.14	0.02	0.03	0.31

Table 14: Verbaliser-Imager Task paired-samples t-test

Table 14 shows the results of the t-tests for related samples comparing the performance of each CS group between the V task and the I task. Both Verbalisers and Imagers performed the V task significantly differently from the I task (p>0.05). As both Verbalisers and Imagers performed the V task better than the I task (table 11) the results of the t-test indicate that there was a significant difference in the performance of the two types of task rather than between the different CS groups.

4.3.3.4 Performance between the cognitive style groups and style of task

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
V_PR * I_PR	1.51	0.23	0.00	0.22	1.65	0.21	0.08	0.23

Table 15: Verbal-Imagery task two-way ANOVA

Table 15 shows the results of the two-way ANOVA between-subjects effects calculations. The PRs of Verbalisers were compared to Imagers (VI) and the PRs of Wholists were compared to Analytics (WA) in the V task (V_PR) and I task (I_PR). No significant interaction between CS and style of task was detected for either dimension.

4.3.4 Identifying cognitive style by monitoring user actions

An important aspect of the experiment was to test whether the CS of subjects could be determined by analysing the way they interact with the system. A number of different types of user actions were monitored during the experiment including:

- In WA tasks, analysing the choices made when browsing though a hypermedia network
- In VI tasks , analysing amount of exploration that users undertake

If a significant difference was found between the CS groups in performing these activities it would be possible to classify users who display the same characteristics.

4.3.4.1 Differences in steps taken whilst browsing hypermedia

The browsing behaviour of the different CS groups in the A task were examined to ascertain whether it is possible to identify the CS of individuals merely by analysing their browsing behaviour. A number of attributes were recorded for each subject, including:

- the number of steps they took to complete the tutorial (A_STEPS)
- the number of times they selected *Next* or *Previous* from the menu (A_EXTRN)
- the number of times they selected *Next* or *Previous* from within the HTML page (A_INTRN)
- the number of times they selected hyperlinks within the HTML page (A_HTML)

Measure	Total	W	A	V	I	WV	WI	AV	AI
A_STEPS	35.67 (7.48)	35.92 (5.99)	35.42 (8.99)	33.09 (5.26)	37.85 (8.53)	32.00 (3.00)	38.71 (6.16)	34.00 (6.78)	36.83 (11.27)
A_EXTRN	6.17 (6.77)	6.25 (7.03)	6.08 (6.80)	4.73 (5.39)	7.38 (7.75)	4.00 (3.39)	7.86 (8.71)	5.33 (6.92)	6.83 (7.25)
A_INTRN	19.33 (7.74)	19.00 (7.92)	19.67 (7.89)	19.45 (7.45)	19.23 (8.28)	18.60 (7.77)	19.29 (8.64)	20.17 (7.83)	19.17 (8.66)
A_HTML	10.38 (7.74)	11.08 (5.95)	9.67 (9.42)	9.00 (4.69)	11.54 (9.66)	9.60 (4.62)	12.14 (6.89)	8.50 (5.13)	10.83 (12.88)

Table 16: Analytic task browsing differences mean results

Table 16 shows the mean number of times (with standard deviation in brackets) each CS group followed each of the different categories of hyperlinks. There were slight variations between the Wholists and Analytics while there were wider variations between the Verbalisers and Imagers. Imagers completed the tutorial in more steps than Verbalisers (I=37.85, V=33.09), and use more external links than Verbalisers (I=7.38, V=4.73), while Verbalisers used more internal links (I=19.23, V=19.45).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
A_STEPS	0.00	0.99	0.00	0.05	2.39	0.14	0.11	0.31
A_EXTRN	0.00	0.96	0.00	0.05	0.85	0.37	0.04	0.14
A_INTRN	0.05	0.83	0.00	0.06	0.00	0.96	0.00	0.05
A_HTML	0.13	0.72	0.01	0.06	0.53	0.48	0.03	0.11

Table 17: Analytic task browsing differences one-way ANOVA

Table 17 show the results of the one-way ANOVA calculations, assessing whether the differences in browsing behaviour was due to CS. None of the CS groups were found to have significantly different browsing behaviour (p>0.10 for all measures).

There were few differences between the performance of each CS group (table 16) and no significant influence that was due to CS was found (table 17). Therefore it is not possible to identify the CS of users by only examining the totals for the above measures.

4.3.4.2 Differences in exploration

The level of exploration in the Verbal-Imagery tasks was recorded for each subject. The measure of exploration records all user activity that was not necessary to complete the set task but the subject initiated without prompting such as clicking on *Help*, *Read Text*, or choosing to view the image resources. These were recorded to assess whether one CS was more inclined to explore the system than another. As Wholists store information serially and Analytics attach new information they already know it was expected that Wholists would prefer to select the *Next* option while Analytics would prefer to follow their own choices of hyperlinks.

Measure	Total	W	A	V	I	WV	WI	AV	AI
V_EXPL	2.13 (3.05)	2.42 (3.85)	1.83 (2.12)	1.91 (3.56)	2.31 (2.69)	2.80 (5.17)	2.14 (3.02)	1.17 (1.60)	2.50 (2.51)
I_EXPL	2.08 (2.10)	2.42 (2.50)	1.75 (1.66)	1.73 (1.56)	2.38 (2.50)	2.00 (1.87)	2.71 (2.98)	1.50 (1.38)	2.00 (2.00)

Table 18: Verbaliser-Imager task exploration mean results

Table 18 shows the mean number of times subjects in each CS group engaged in exploration activities in the V task (V_EXPL) and the I task (I_EXPL). There are slight variations between the CS groups. Wholists opposite to expectations performed more exploration activities than Analytics while Imagers performed more exploration activities than Verbalisers.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
V_EXPL	0.23	0.63	0.01	0.08	0.07	0.80	0.00	0.06
I_EXPL	0.45	0.51	0.02	0.10	0.29	0.60	0.01	0.08

Table 19: Verbaliser-Imager task exploration one-way ANOVA

Table 19 shows the results of the one-way ANOVA between-subjects effects calculations assessing the effect each CS dimension had on the performance of subjects within each measure. None of the groups were found to have performed significantly differently from each other.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
V_EXPL	-0.31	22.00	0.76	-0.40	1.28
I_EXPL	-0.76	22.00	0.46	-0.66	0.87

Table 20: Verbaliser-Imager Task exploration independent-samples t-test

Table 20 shows the results of the independent-samples t-test calculations that compared the mean exploration values of Verbalisers against Imagers within each measure. The exploration activity of Verbalisers and Imagers was not found to be significantly different.

Pairs	Total	W	A	V	I	WV	WI	AV	AI
V_EXPL I_EXPL	0.95	1.00	0.92	0.88	0.92	0.77	0.54	0.74	0.73

Table 21: Verbaliser-Imager Task exploration paired-samples t-test

Table 21 shows the results of the paired-samples t-test calculations comparing the mean exploration activity of Verbalisers and Imagers between the V task and the I task. The exploring activity of Verbalisers and Imagers was not found to be significantly different for any of the CS groups (P>0.10).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
V_EXPL * I_EXPL	0.51	0.49	0.03	0.10	0.29	0.60	0.01	0.08

Table 22: Verbal-Imagery task exploration two-way ANOVA

Table 22 shows the results of the two-way ANOVA between-subjects effects calculations assessing the effect of CS between the results of the V task and the I task. The exploring activity of Verbalisers, Imagers, Wholists or Imagers were not found to be significantly different.

There was more exploration by all subjects (Total) in the V task than the I task, Imagers explored more than Verbalisers and Wholists explored more than Analytics in both the V task and the I task (table 18). However, neither the WA dimension nor the VI dimension were found to significantly effect the exploration activity of subjects in the V task or the I task by the one-way ANOVA between-subjects effects (table 19) or two-way ANOVA calculations (table 22). The exploration activity was not found to be significantly different when comparing the exploration activity of each CS group within each measure (Table 20) or between the V task and the I task (table 21).

The location where subjects clicked were also recorded in all tasks within the experiment in order to assess whether one CS group was more likely than others to click on images or text. The results of these assessments would establish whether it was possible to identify the CS of a user by monitoring the location of their mouse clicks. It was expected that Imagers would be more likely to click on images than text and that Verbalisers would be more likely to click on text than images.

Measure	Total	W	A	V	I	WV	WI	AV	AI
Mean	86.26	88.04	84.48	88.32	84.52	87.37	88.51	89.10	79.87
Std. Dev.	22.54	21.79	24.10	21.28	24.28	23.74	22.23	21.28	27.81

Table 23: Mouse-clicks selected images (%) mean results

Table 23 shows the mean percentage of times each CS group clicked on images rather than corresponding text labels throughout the whole experiment. As indicated by the red background Verbalisers (88.32%) unexpectedly clicked on images a larger percentage of times than Imagers (84.52%).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
Images	0.13	0.73	0.01	0.06	0.17	0.68	0.01	0.07

Table 24: Mouse-clicks selected images (%) one-way ANOVA

Table 24 shows the results of the one-way ANOVA between-subjects effects calculations assessing the effect of CS in influencing the location of where subjects clicked. No significant effect was found to be due to CS.

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
WA	0.38	22.00	0.71	3.55	9.38
VI	0.40	22.00	0.69	3.80	9.41

Table 25: Mouse-clicks selected images (%) independent-samples t-test

Table 25 shows the results of the independent-samples t-tests comparing the mean values of Wholists against Analytics (WA) and Verbalisers against Imagers (VI). Unexpectedly Verbalisers selected images more

(88.32%) than Imagers (84.52%, table 23), however, this effect is not supported by the one-way ANOVA between-subjects effects calculations (table 24) or the t-test between the CS groups (table 25) that found no significant difference between the CS groups.

It is not possible to identify a persons' CS by recording the number of times users select images in preference to text. The subjects' actions while they performed the experiment were analysed in order to identify traits of CS groups that would make general recommendations for identifying the CS of users of multimedia systems. However it was not possible to identify significant differences between the CS groups. It may be possible to identify CS by the choices of hyperlinks that subjects made, however this identification would be specific to the subject matter that was being presented and not a general rule that could be followed for all types of information.

4.4 Conclusions from the results of the experiment

The experiment was set up to test the assumption that subjects would perform better using the interface that reflected their CS. It was important to determine how the Wholist subjects performed compared to the Analytic subjects in the WA tasks, and how the Verbaliser subjects performed compared to the Imager subjects in the VI tasks.

Figure 65 summarises the results of the experiment listing all the significant or marginally significant results of the experiment associated with each of the CS groups. The tasks in which each CS group performed significantly better than the opposite CS are listed, stating whether this was expected or unexpected.

It was expected that subjects would perform better using the interface that was designed to be suitable for their CS. While there was some evidence to support some of the expectations there was no significant difference in performance in most measures by the different CS groups and there is also evidence that performance was opposite to expected (figure 65).

Wholists who performed the W task first performed better than Wholists who performed the A task first. There were identified differences in performance between the Wholists and Analytics but where there were significant differences Analytics performed better than Wholists whether the result was as expected or was opposite to what was expected. No significant differences of performance were identified between the Verbalisers or Imagers in the VI tasks.

Attempts to identify differences in the browsing or exploration behaviour of subjects or the preferred location of mouse-clicks failed to find any significant differences between the CS groups. The exploration figures were low and may hide significant differences that longer use of the system may reveal.

Wholists **As Expected** **PR1** (W (W Task 1) * W (A Task 1))	**Analytics** **As Expected** **PR1** (W (W Task 1) * A (A Task 1)) **PR2** (W (A Task 1) * A (A Task 1)) **Unexpected** **W_PR** **PR1** (W (W Task 1) * A (W Task 1) **PR2** (W (W Task 1) * A (W Task 1)
Verbalisers No difference	**Imagers** No difference

Figure 65: Summary of Experiment Results

The results of the experiment did produce some evidence that the CS of subjects was influencing their performance, however this was not always in the expected manner. The were three main possibilities to why the results of the experiments were not as expected:

1. The assumptions of how the different CS groups would perform were incorrect.
2. The tasks were not designed in a manner that would reflect the differences between the CS groups
3. A combination of the other first two possibilities.

These three possibilities were interdependent. If the experiment tasks were designed in a manner that conformed to the recommendations in the literature associated with the CSA test in both content and context then the assumptions of how the different CS groups would perform were incorrect. If, however, there were differences between the design of the experiment tasks and the CSA recommendations then the assumptions would be inadequate to explain the performance of the CS groups in the context of the experiment. In this case other factors would have affected the performance of the CS groups which are contained in the differences between the CSA recommendations and the experiment tasks.

There are a number of differences between the design of the experiment tasks and the experiments that found significant differences between the performance of CS groups, therefore the differences between the experiments were examined in order to identify features that may have affected performance:

1. Incorrect assumptions were drawn from the CSA literature. The assumptions were drawn from general statements made within the CSA manual, with additional recommendations drawn from the results of experiments reported in the associated published literature.
   - Some of the assumptions were general but were subject to other factors, for example, Wholists were expected to perform better than Imagers when presented with text, however Imagers were expected to perform better than Verbalisers if the text contained a high degree of descriptive, high-imagery words.

- Some of the assumptions were based on strong observed links between CS and performance, such as Verbalisers performing better with text and Imagers performing better with images (Riding & Ashmore, 1980; Riding et al., 1989).
- Other assumptions were based on weaker links between CS and performance, such as Analytics performing better at mathematical tasks than Wholists (Riding & Rayner, 1998).

2. The tasks used in the experiment were designed to reflect the way each CS group process information rather than to contain the features that would improve their performance:
   - The W task presented information serially as a single video clip. Although the presentation of information reflects the way Wholists process information, Wholists may benefit more from a presentation that broke the information into smaller chunks to ensure they do not miss the detail of the components that make up the whole.
   - The A task presented information in smaller chunks within a hypermedia network that allowed a number of routes through the path. This method of presentation reflected the way Analytic store information, but Analytics may have benefited more from being guided through the information to allow them to gain a greater appreciation of how the pieces of information fit together.
   - The V and I tasks presented information using text or graphics, however performance was measured in terms of how well they performed a task. Their performance depended on how they perceived the instructions and data, but assessed how they applied their understanding of the task rather than their original understanding.
3. The complexity of tasks. The set of experiments described in this chapter are relatively complex while the experiments described in the CSA literature are relatively simple:
   - The Wholist-Analytic experiment used totally different styles of presentation while the experiments described in the CSA literature changed only small aspects of the presentation, such as the location of a title (Douglas & Riding, 1993), or the amount of information that is presented in each step (Riding & Sadler-Smith, 1992).
   - The Verbal-Imagery experiment assessed how individuals performed a complex task using text or images, while the experiments described in the CSA literature assessed how individuals perceived text against equivalent images (Riding & Ashmore, 1980; Riding et al., 1989; Riding & Douglas, 1993), high against low imagery words (Riding & Calvery, 1981), or their preferred format of presentation (Riding & Watts, 1997; Riding & Reed, 1996).

   Where the performance of individuals in different CS groups were compared in more complex tasks, such as the strategies adopted by subjects searching databases (Wood et al., 1996), comparing the methods of retrieving information from large textbooks against hypermedia (Wilkinson et al., 1997), or different types of computer-based training packages (Boles & Pillay, 1999) there were weaker links between performance and CS.
4. The effect of the other dimension. The set of experiments described in this chapter are relatively complex and each contain aspects that may be suitable for more than one CS dimension.
   - The Wholist and Analytic tasks contained different mixes of text and images, audio and video, which may effect the performance of Verbalisers and Imagers in a different manner.

- The Verbaliser and Imager tasks are structured in a manner that may suit Wholists or Analytics to a greater or lesser degree.

There is a possibility that the aspects that affected the performance of other CS dimension may have more influence on performance of subjects than the aspects that suited the CS being examined, e.g. the aspects that suit Verbalisers or Imagers in the Wholist-Analytic tasks may have affected performance more than the aspects that suited Wholists or Analytics.

5. The media used in the experiment. The set of experiments described in this chapter used multimedia interfaces that used text, images, audio and video to present information, while the experiments described in the CSA literature have a restricted use of media.
   - Some experiments use text alone (Riding & Calvery, 1981; Riding & Sadler-Smith, 1992; Douglas & Riding, 1993; Wilkinson et al., 1997).
   - Other experiments test the difference in the perception and preference of text compared to images, or a combination of text and images (Riding & Ashmore, 1980; Riding et al., 1989; Riding, 1991; Riding & Douglas, 1993; Riding & Reed, 1996; Riding & Watts, 1997; Riding, 1998).
   - Audio has been used in some experiments, using speech as a substitute for text (Riding & Taylor, 1976; Riding & Calvery, 1980; Riding & Anstey, 1982).
   - The effect that CS has on the perception of multimedia has not yet been fully examined in published literature.
6. The influence of other factors that have not yet been identified.

All of the above issues needed to be investigated in a new set of experiments.

- The assumptions drawn from the CSA literature need to be tested by designing tasks that represent individual recommendations.
- Tasks should represent the recommendations rather than reflect the way individuals process information.
- Tasks should concentrate on individual aspects of CS rather than be complex.
- Tasks should assess the performance of individuals along one dimension (or assess the stronger influence where recommendations have implications for both dimensions).

The effect of multimedia should be examined by designing tasks using single media, and combinations of media.

The design and results of the new sets of experiments are discussed in the following chapters.

5 Design of an experiment testing the effect of Users' Cognitive Style on their performance in tasks using different media

The results of the experiment that presented tasks designed to reflect the cognitive style (CS) of subjects did not produce the expected results (chapter 4) therefore the conclusion is that another factor must have been affecting the performance of subjects. This chapter discusses the design of another experiment that investigated whether the other factor was the type of media used in the original experiment.

First the background considerations of the experiment are discussed, including the definition of the problem that the experiment was attempting to solve, the aims of the experiment and the method that was undertaken in conducting the experiment. Next the implementation of the experiment is discussed, including a description of the tasks that were performed and what the expected performance of each CS group was. The results of the experiment are presented and discussed in chapters 6 and 7.

5.1 Planning the experiment

In order to plan the second experiment a number of background considerations needed to be examined. The problem the experiment was attempting to solve was to discover whether the media used in the presentation of information affected the performance of different CS groups. Therefore differences in the way different types of media are perceived were investigated. The aims of the experiment were to investigate whether the actual performance of the CS groups were as predicted and so the expected performance of the CS groups in a range of tasks were examined.

5.1.1 The problem definition

The relative performance of the CS groups in the experiment described in chapter 4 was not as expected. Subjects were expected to perform relatively well using the interfaces that were designed to suit their CS and perform relatively poorly in the tasks that were designed to suit the opposite style, however this was not always the case. Other factors in addition to the style of interface were influencing the performance of subjects. In order to determine what the other factors were the differences between the experiment described in chapter 4 and other experiments that used the CSA were examined. In particular differences in the use of media in the experiments were examined.

The following sections explore differences in the way information that is presented using multimedia computers is perceived and which types of information are expected to suit the different CS groups.

5.1.1.1 The perception of multimedia information

The experiment described in chapter 4 was conducted on a computer with a multimedia interface using text, diagrams, photographic images, audio sound effects, text-to-speech, recorded speech and video while most of the published experiments that examined the effect of the CSA categorisation of CS have not used a multimedia interface. The CSA test uses text and simple geometric shapes (Riding, 1991; Riding, 1998) and the experiments that measured the performance of different CS groups used text (Riding & Calvery, 1981; Douglas & Riding, 1993) or text and images (Riding & Ashmore, 1980; Riding et al., 1989; Riding & Sadler-Smith, 1992; Riding & Douglas, 1993; Riding & Watts, 1997). Where audio has been used it has been in the form of spoken words (Riding & Taylor, 1976; Riding & Calvery, 1980; Riding & Anstey, 1982).

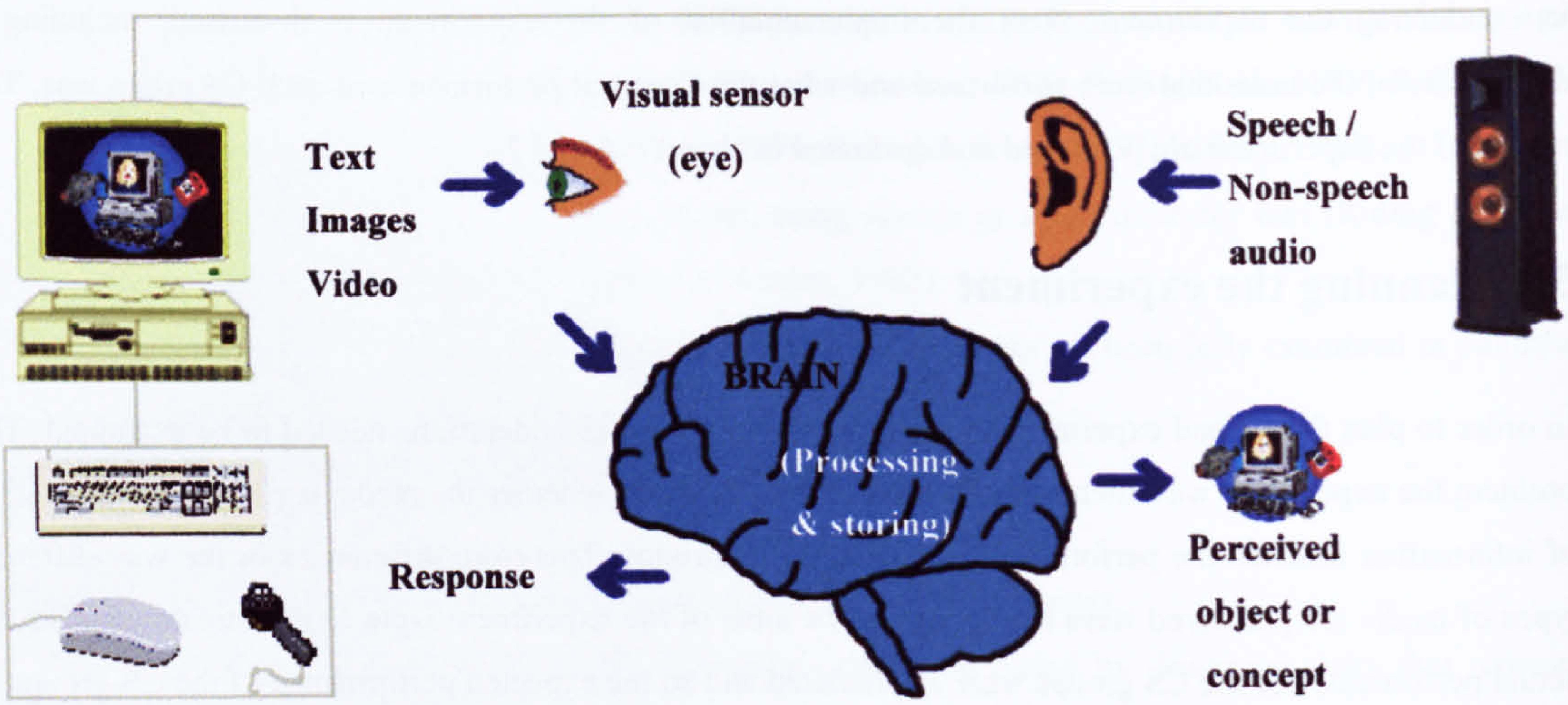


Figure 66: Perception of Multimedia information

The use of multimedia was identified as a factor that may have influenced the performance of subjects. In order to devise an experiment that measures the effect of multimedia on the performance of the CS groups an understanding is needed of how the different media presented in multimedia computer systems are perceived. Different types of media presented by a multimedia computer system are received by different sensory organs and processed by different parts of the brain. Visual information from the screen, including text, images and video are sensed by the eye and audio information, including speech and non-speech sounds, are sensed by the ear (figure 66). The brain makes sense of the sensations detected by the sense organs by processing the information depending on the context and the persons' memory and expectations, producing an internal model of the perceived object or concept (Goldstein, 1989). The user's responses to the presentation are based on their internal model of the information.

Sensations that are detected by the sense organs are received in different parts of the brain. The main cortical receiving areas of the brain that are associated with perceiving multimedia are shown in figure 67. Visual information is received in the occipital lobe at the back of the brain while auditory information is received in the temporal lobe around the lower part of the brain (Kandel & Schwartz, 1984; Goldstein, 1989; Anderson, 1995). The main receiving areas of other sensations except taste have also been identified. Touch is associated with the parietal lobe and smell is associated with the underside of the frontal lobe (Goldstein, 1989).

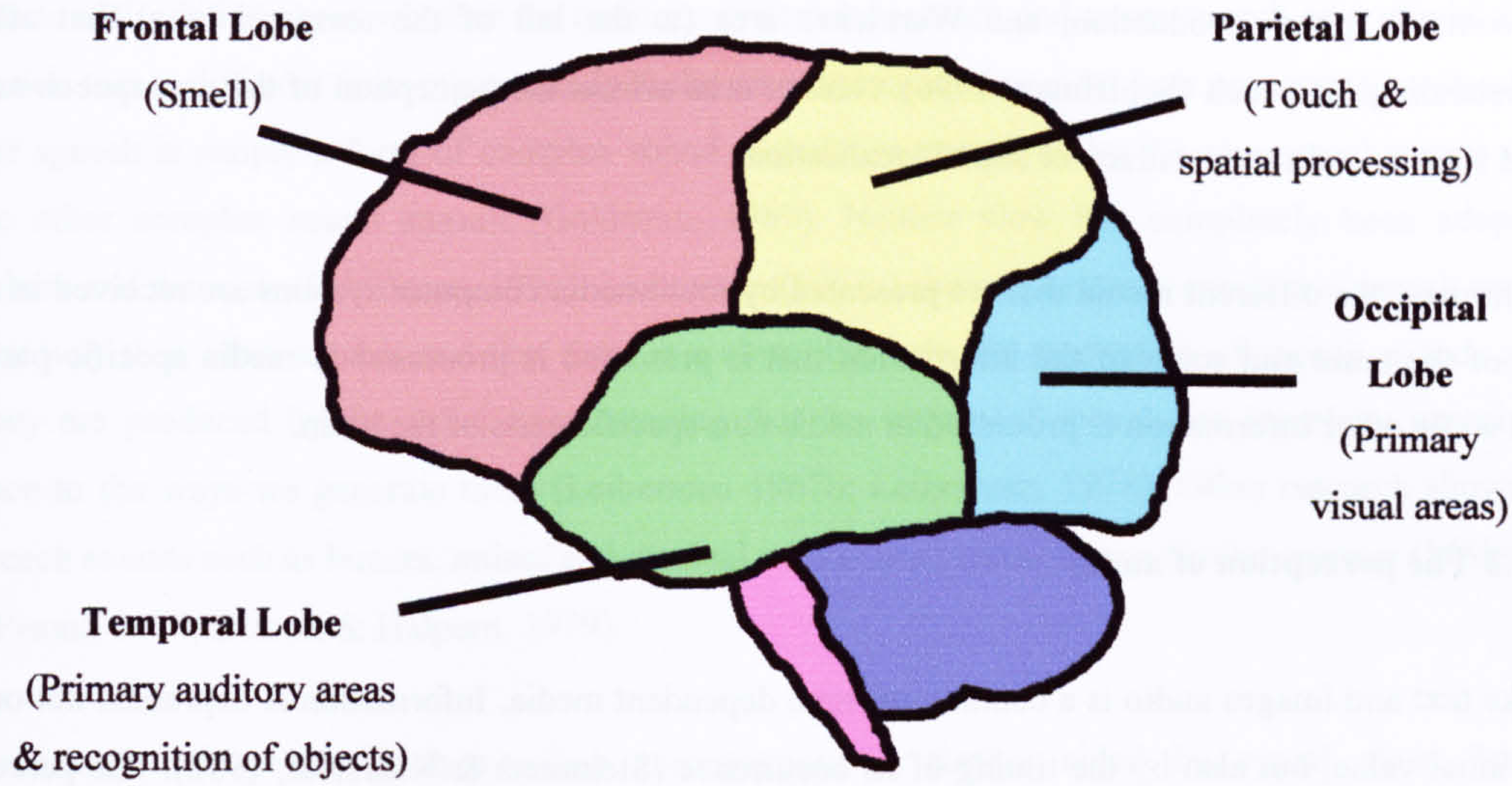


Figure 67: Main cortical receiving areas of the brain

The main cortical receiving areas of sensations have been identified but it is more difficult to identify the areas where thinking, reasoning and planning takes place. The receiving areas are not necessarily the places where the information is processed and the perceptions are determined. The left and right sides of the brain are divided into areas of specialisation. The left hemisphere specialises in simple language construction and non-verbal associations, while the right hemisphere specialises in language including speech, writing, and performing calculations (Sperry, 1968; Gross, 1996).

Some types of information are processed by the same area of the brain regardless of media while some areas of the brain are more media specific (Goldstein, 1989). The processing of verbal and visual information takes place in different parts of the brain and there are separate representations for verbal and visual information (Paivio, 1971; Paivio, 1986). Some visual information (geometric objects) tend to be stored according to spatial position, whereas other information, such as words tend to be stored according to linear order (Santa, 1977).

There are two different types of imagery information that is processed by the brain depending on the spatial and visual attributes of the information and different areas of the brain appear to be responsible for supporting the different aspects (Farah et al., 1988). Processing of information which involves making spatial judgements takes place in the parietal lobe that makes sense of spatial information received from any sense organ (Anderson, 1995). Other aspects of the visual experience such as the recognition of colour, the recognition of patterns or visual objects and identifying the location of objects are unique to the visual senses and are handled by the temporal lobe (Anderson, 1995). Specific areas within the temporal lobe including the inferotemporal cortex and the superior temporal cortex appear to contribute to specific, complex feature detection (Gross, 1972; Bruce et al., 1981; Desimone et al., 1984; Schiffman, 1996).

The main speech areas of the brain have been identified as Bracas area (in the lower part of the frontal lobe) that controls speech production, and Wernickes area (to the left of the temporal lobe) that affects the understanding of speech (Schiffman, 1996). Neither area affects the perception of the non-speech aspects of sound such as auditory accuracy or sound localisation.

In summary, the different media that are presented by multimedia computer systems are received in different parts of the brain and some of the information that is presented is processed in media specific parts of the brain while other information is processed in media non-specific parts of the brain.

5.1.1.2 The perception of audio

Unlike text and images audio is a continuous, time dependent media. Information is expressed not only in its individual value, but also by the timing of its occurrence (Steinmetz & Nahrstedt, 1995). The perception of audio is concerned with the perception of objects location in space by sound alone, the perception of non-speech sounds (particularly music) and the perception of speech (Handel, 1993).

The use of audio in multimedia computer systems can be divided into the presentation of speech and non-speech sounds (Brewster, 1998). Speech includes recorded voice or synthetic voices generated with text-to-speech applications. Associating non-speech sounds (*auditory icons* and *earcons*) with events has been shown to improve the interaction of graphical human-computer interfaces (Gaver et al., 1991; Blattener et al., 1992; DiGiano et al., 1993; Brewster et al., 1994). Auditory icons are everyday sounds that can intuitively be associated with system events (Gaver et al., 1991; Gaver, 1993a; Gaver, 1993b) while *earcons* are abstract, musical tones that can be used in structured combinations to indicate audio messages (Blattner et al., 1989; Brewster, 1998).

The major psychological (phenomenological) aspects relevant for the perception of audio are pitch, loudness, timbre and location (Beaumont, 1988; Handel, 1993; Gross, 1996; Elsom-Cook, 2001). Pitch is the perceived frequency of a sound, loudness is the intensity of sound, timbre is the quality of the sound such as the difference between two instruments playing the same note and the location is where the sound is coming from. In addition consonance and dissonance can occur when two or more tones are played simultaneously. For the purposes of the current investigation the location of the source of the sound is less important than the perception of speech and non-speech sounds because the origin of all sounds will be from the speakers attached to a multimedia computer.

Speech is a stream of words made up of phonemes which are the smallest units of speech sounds of a language that enables one utterance to be distinguished from another (Schiffman, 1996). Speech is continuous with no obvious word boundaries and often contains distortions due to accents, dialects, voice qualities, background noises and sound omissions, however words retain their identity and are perceived accurately because of a learned familiarity with a language (Goldstein, 1989; Anderson, 1995; Schiffman, 1996).

Opinion is still divided about whether the auditory system recognises and treats speech as a special form of stimulation that is different from other sounds in the environment and uses its own processing mechanism, or whether speech is simply a form of complex sound stimulation perceived by the same mechanisms used to analyse other complex sound stimuli (Goldstein, 1989). Neither view has completely been adopted by researchers and theorists (Schiffman, 1996). Lieberman (1967a) showed listeners categorise speech sounds in different way than other sounds and that there is a close link between perception of speech sounds and the way they are produced by the vocal tract meaning that the sounds of speech are somehow perceived by reference to the ways we generate them (Leiberman 1967b; Leiberman, 1978). Other research showed that non-speech sounds such as buzzes, noises and musical stimuli are perceived in a similar manner (Miller et al., 1976; Pisoni, 1977; Zatorre & Halpern, 1979).

The perception of speech in face-to-face conversations is further aided by visual clues from the accompanying movements of the face and lips (McGurk & MacDonald, 1976). Historically multimedia PCs were not able to support long sequences of video and audio showing lip-synchronisation and so information presented by multimedia computer systems was rarely accompanied with the corresponding visual clues.

Music also appears to be a special case (Schiffman, 1996). We perceive music as much more than a series of discrete sounds and instead the sounds are psychologically integrated and heard as well formed organised and coherent patterns that we recognise as musical phrases or melodies. What distinguishes music from a mere collection of sounds appears to be the organised nature of the stimulation and the relation among the individual tones or their context (Schiffman, 1996).

5.1.1.3 Differences in perception between the cognitive style groups

Using the CSA manual and knowledge about how information presented by different types of media are processed in the brain it is possible to draw up a list of tasks that each CS group is expected to perform best.

It was expected that a persons' verbal skills were not related to their spatial skills because each is processed by different parts of the brain (Goldberg et al., 1977; MacLeod et al., 1978; Anderson, 1995). The relative performance between verbal and spatial skills are represented by the persons' CSA verbal-Imagery classification (Riding, 1991). Verbalisers are expected to perform better than Imagers in the tasks that contain low-imagery words but not in the tasks that contained high-imagery words (Riding, 1991; Riding, 1998). Where there is a mixture of high and low-imagery words used (as in most complex tasks, such as answering comprehension questions) the expectation is that Verbalisers will perform better than Imagers in tasks that use words (Riding, 1996). Verbalisers are also expected to perform mathematics calculations better than the

Imagers (Riding & Rayner, 1998). The CSA manual does not state whether these same relative performances are expected when the words are presented using speech instead of text.

Imagers are expected to perform better than Verbalisers in the tasks that use high-imagery words (Riding, 1991; Riding, 1998). Imagers are also expected to perform better than Verbalisers in tasks that use images and diagrams to present information. The CSA manual does not state whether Imagers are expected to perform better than Verbalisers in all types of task that do not use words, such as tasks that use non-speech audio.

Wholists are expected to perform better than Analytics in the tasks that require subjects to assess the overall condition of objects or concepts, including general comprehension questions and the comparison of complete objects and shapes. Wholists are also expected to perform better than Analytics in the tasks that require subjects to process information depending on the order that it was presented such as sets of procedural instructions or directions (Riding, 1991).

Analytics are expected to perform better than Wholists in tasks that require subjects to assess the details of parts or circumstances that do not depend on the order in which the information is presented, such as detailed comprehension questions, reading maps or assessing whether one object is part of another. Although there is stronger evidence that differences in the performance of mathematical questions depends on subjects' Verbal-Imagery category the Analytics were expected to perform the mathematics questions better than the Wholists (Riding & Rayner, 1998).

5.1.2 Aims of the experiment

A hypothesis was developed from examining the background issues of the problem:

- A persons' CS will affect their performance in a predictable manner when performing tasks that use the same media that are used in the CSA.
- A persons' CS will affect their performance in a predictable manner when processing information using the same parts of the brain that were used during the CSA test.
- A persons' CS will not affect their performance in a predictable manner when processing information using different parts of the brain than the parts that were used during the CSA test.

An experiment was planned to test the above hypothesises using a range of tasks presenting information using a number of different types of media and combinations of media. There were two main aims for conducting the experiment:

1. To identify whether the effect CS has on the performance of subjects is different depending on the media that is used to present information.
2. To identify which types of task are performed best by each of the CS groups.

5.1.3 Experiment method

There were two main questions that the experiment was attempting to answer. In order to answer the first question of whether the effect of CS is different depending on the media used to present information a series of tests were prepared presenting information using different types of media on a multimedia PC. Each test contained a number of tasks that were designed to contain aspects that were expected to be suitable for different CS groups. Any difference between the expected performance and actual performance among the media tests would indicate that the influence CS has on performance was dependent on the media that was presented. In order to answer the second question of identifying the tasks that were performed better by each CS group the relative performance of each CS group between the tasks were ranked.

In each test the subject was presented with information using different media and was then asked to answer questions to test their understanding of the information. The performance of subjects was measured by recording the number of questions they answered correctly and recording the time it took them to answer the questions.

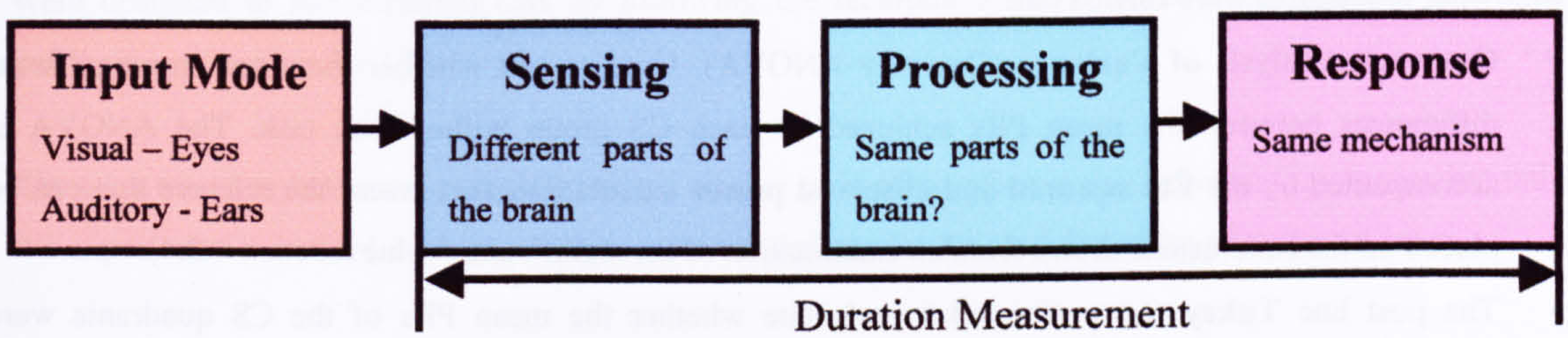


Figure 68: Processes involved in answering questions

Figure 68 illustrates the processes involved in answering a question in the experiment. The duration measurement records the time spent for the three processes of sensing, processing and response. It is not possible to separate these processes in the duration measurement and so it is not possible to identify which process is affected most by the input of information using different media.

The sensing mechanism is different for each mode of input, involving the eyes for visual information (text, images and video) and the ears for auditory information (audio and the video soundtrack). These sensing activities are affected by the parts of the brain that receive the information and the rate in which the information arrives. Visual information is gathered by the scanning movements of the eye which allows information to be gathered in a non-serial manner and at a rate that is determined by the individual. Auditory information in contrast is presented serially at a rate that is determined externally. In the tests that present visual information the recorded duration includes the time subjects read the question as these varied between subjects. In the audio and video test the time the questions are read by the system does not change between subjects and so this time is excluded from the subjects' duration figures. Subjects were chosen who had no defects of sight or hearing so the results were not affected by differences in the sensing processes of individual subjects.

The processing of the information involves the individual making sense of the information and determining the correct answer. Different types of information are processed by different parts of the brain which are governed by the individual's CS. Some types of information such as language are expected to be processed by the same parts of the brain whether the input is visual or auditory, while other types of information are processed in areas of the brain that are associated with the mode of input.

The response process involves the subject entering their answers by clicking the mouse. This is a mechanical process and it is assumed that once the answer is determined the response time will be the same for individuals independently of the style of question.

As in the first experiment (chapter 4) the performance of subjects was assessed by creating a performance ratio (PR) of score (the percentage of questions answered correctly) divided by duration (the average time taken to answer one question). The mean PRs of Wholists were compared against Analytics, the mean PRs of Verbalisers were compared against Imagers, and the mean PRs of the CS quadrants were compared against each other. To test the statistical significance of the observed differences between the mean PRs the following procedures were carried out:

- **One-way Analysis of Variance** (One-way ANOVA). Used to test whether there are any significant differences between the mean PRs achieved by each CS group within each task. The ANOVA is accompanied by the **Eta squared** and **observed power** calculations that assess the reliance that can be placed on the conclusions drawn from an examination of the significance value (section 4.2.4).
- The post hoc **Tukey** test performed to calculate whether the mean PRs of the CS quadrants were significantly different from each other.
- **Two-way Analysis of Variance** (Two-way ANOVA). Used to compare the performance of two CS groups in two tasks. Testing whether any difference in performance of one task that is attributed to CS was matched by a corresponding effect in the opposite style of task.
- **Paired-samples t-test.** Used to test whether a CS group performed two tasks significantly differently. Where there was no significant difference in performance the tasks are given equal rank.

For each type of media a range of tasks were prepared that were suited to different CS groups. The relative performance of the CS groups were compared in each type of task to assess whether the CS group that was expected to perform best actually did. Because of the different nature of each media it was not possible to create equivalent tasks for each media and so comparisons across media were made by comparing performance in groups of task that were suitable for different CS groups.

5.2 Implementation of the experiment

The experiment presented subjects with a range of tasks using a variety of media. This section discusses the choice of media used in the experiment and the design of the tasks. For each media test the tasks are described and the expected relative performance of the CS groups are listed.

Five separate tests were prepared using different media and each test contained a number of different tasks. The choice of media used in the experiment reflected the media used in the CSA test contrasted with the other types of media that are presented by multimedia computers.

The literature supporting the CSA manuals states that in general Verbalisers prefer text and Imagers prefer images (Riding, 1991; Riding, 1998) therefore two tests were prepared one presenting information using text and the other presenting information using images. A third test was prepared to test the effect of presenting information using a combination of text and images. In addition two other tests were prepared to reflect the developments of multimedia PCs since the CSA test was first produced, one using audio and one using video. The video test presented information using a combination of still and moving images, text, speech, music and sound effects.

In each task subjects were presented with short pieces of information and their perception of the information was tested by asking subjects to select the appropriate answer in a series of multiple-choice questions. The tasks were designed to contain aspects that suit different CS groups and reflect the uses of each media. Tasks were designed to suit different CSs by following the recommendations in the CSA manuals and related publications (section 5.1.1.2).

The tests were implemented using VB using a similar style of interface to the *Telecare Companion* but unlike the experiment described in chapter 4 they were not designed to be modules of the prototype system.

5.2.1 The text test

The tasks used in the text test were designed to reflect the nature of text and the way text is used within multimedia computer systems. The role of text within multimedia systems is to present information using an organised sequence of symbols to represent language. At its most basic level text is comprised of letters that are the symbols that represents sounds. Letters combine to form words that have meanings, not because they inherently contain the meaning but because of an artificial association between the symbols and a concrete object or abstract concept that has been learned (Elsom-Cook, 2001). The way in which people habitually process the meaning behind words determines their Verbal-Imagery CS classification (Riding, 1998). For a person to understand the meaning of the text they have to visually recognise each symbol, build the words, detect the context and the fetch the meaning associated with the word from memory. Unlike speech text presents words as discrete entities which can be accessed independently of time (Steinmetz & Nahrstedt, 1995).

The text test presents information using text and tests subjects' understanding by asking questions. Subjects are required to make comparison evaluations, perform calculations and answer comprehension questions.

5.2.1.1 Text test comparison of concepts task

In the *comparison of concepts* tasks (figure 69) subjects were asked to compare pairs of low-imagery words that are not directly associated with objects (such as names of sports or careers) and decide whether they were the same type, e.g.

Walk and Run are the same type

The above statement is true because they are both methods of moving.

Spend and Save are the same type

The above statement is false because they are opposites.

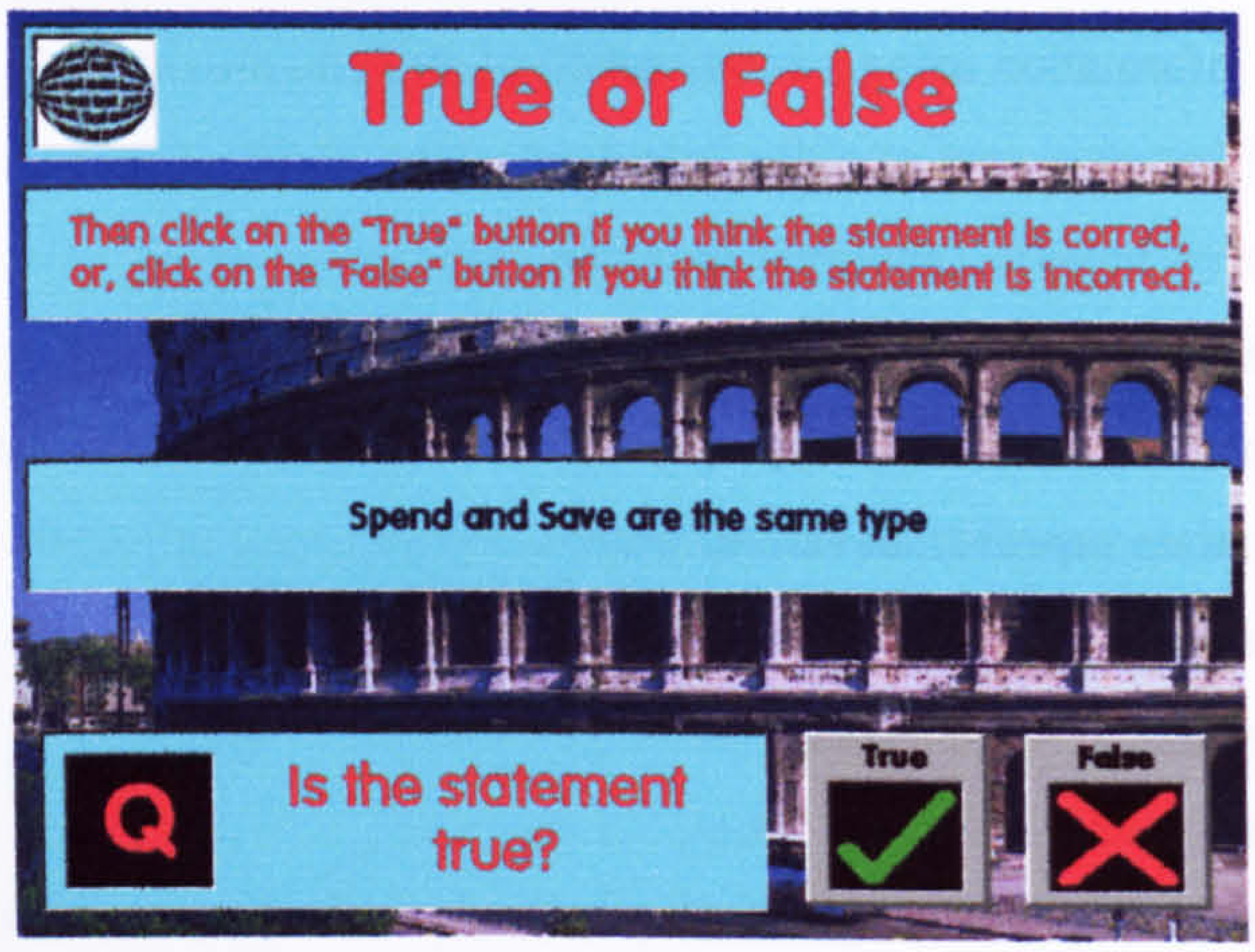


Figure 69: Text comparison of concepts task interface

Subjects enter their answer by clicking on the True or False buttons as shown in figure 69. The *comparison of concepts* task were similar in design to the Verbaliser questions in the CSA test (Riding, 1991; Riding, 1998) and so it was expected that this task would be performed better by Verbalisers than Imagers because the questions use low-imagery words.

5.2.1.2 Text test comparison of objects task

In the *comparison of objects* task (figure 70) subjects were asked to compare pairs of high-imagery words that describe the attributes of objects and decide whether they were the same colour, size, type etc. e.g.

Duck and Goose are the same type

The above statement is true because they are both types of birds.

Cat and Mouse are the same size

The above statement is false because cats are larger than mice.

Like the *comparison of concepts* task subjects enter their answer by clicking on the True or False buttons as shown in figure 70. The *comparison of objects* task was similar in design to the Imager questions in the CSA test (Riding, 1991; Riding, 1998). As a general rule Verbalisers are expected to perform better than Imagers with text, however it was expected that Imagers would perform the comparison of objects task better than Verbalisers because the questions use high-imagery words.

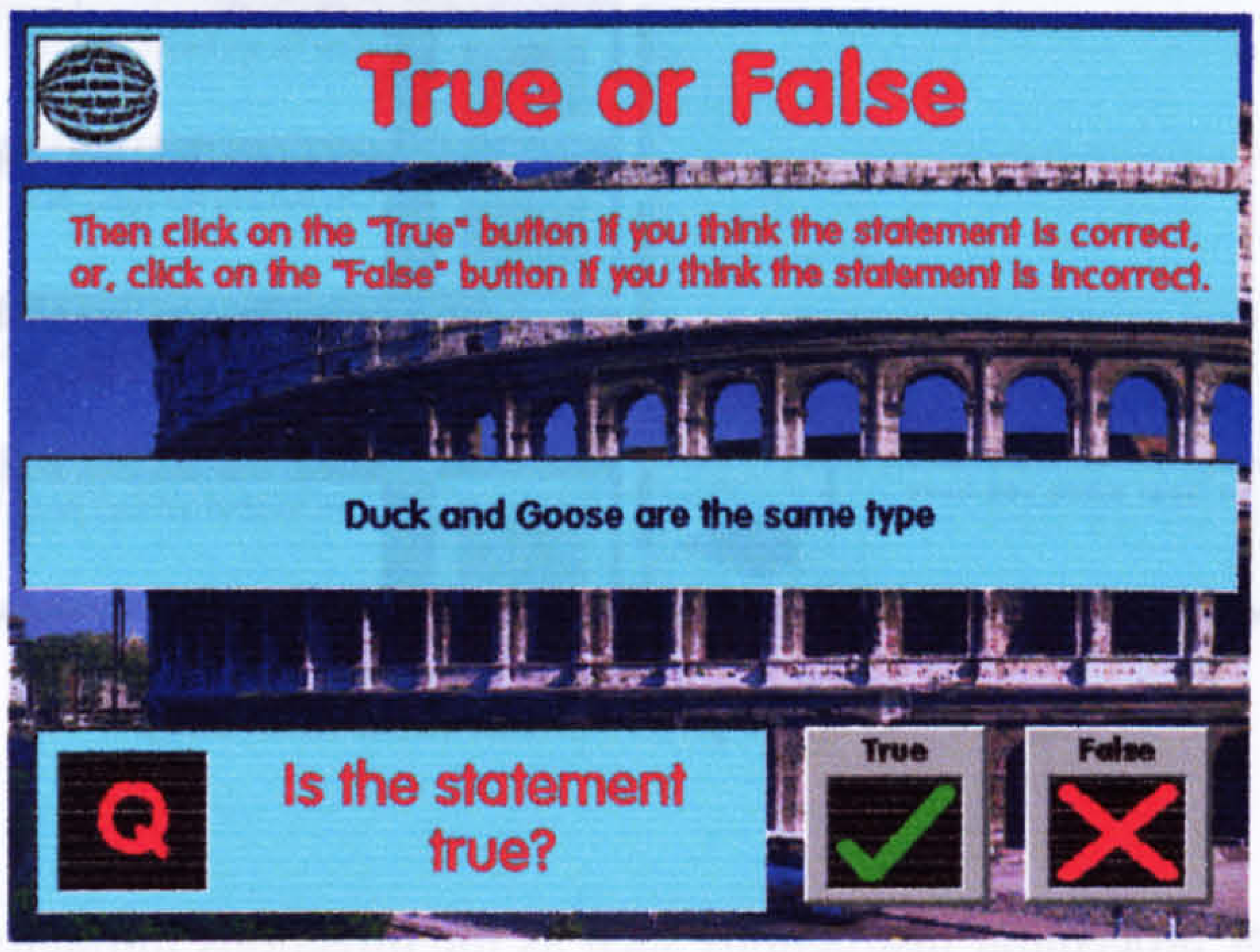


Figure 70: Text comparison of objects task interface

5.2.1.3 Text test mathematics task

In the *mathematics* task subjects were asked to perform simple addition, multiplication and division calculations. Subjects performed the calculation in their heads and entered their answer by selecting the appropriate number from the tens and units columns (figure 71). It was expected that the *mathematics* task would be performed better by Verbalisers and Analytics (Riding & Rayner, 1998).

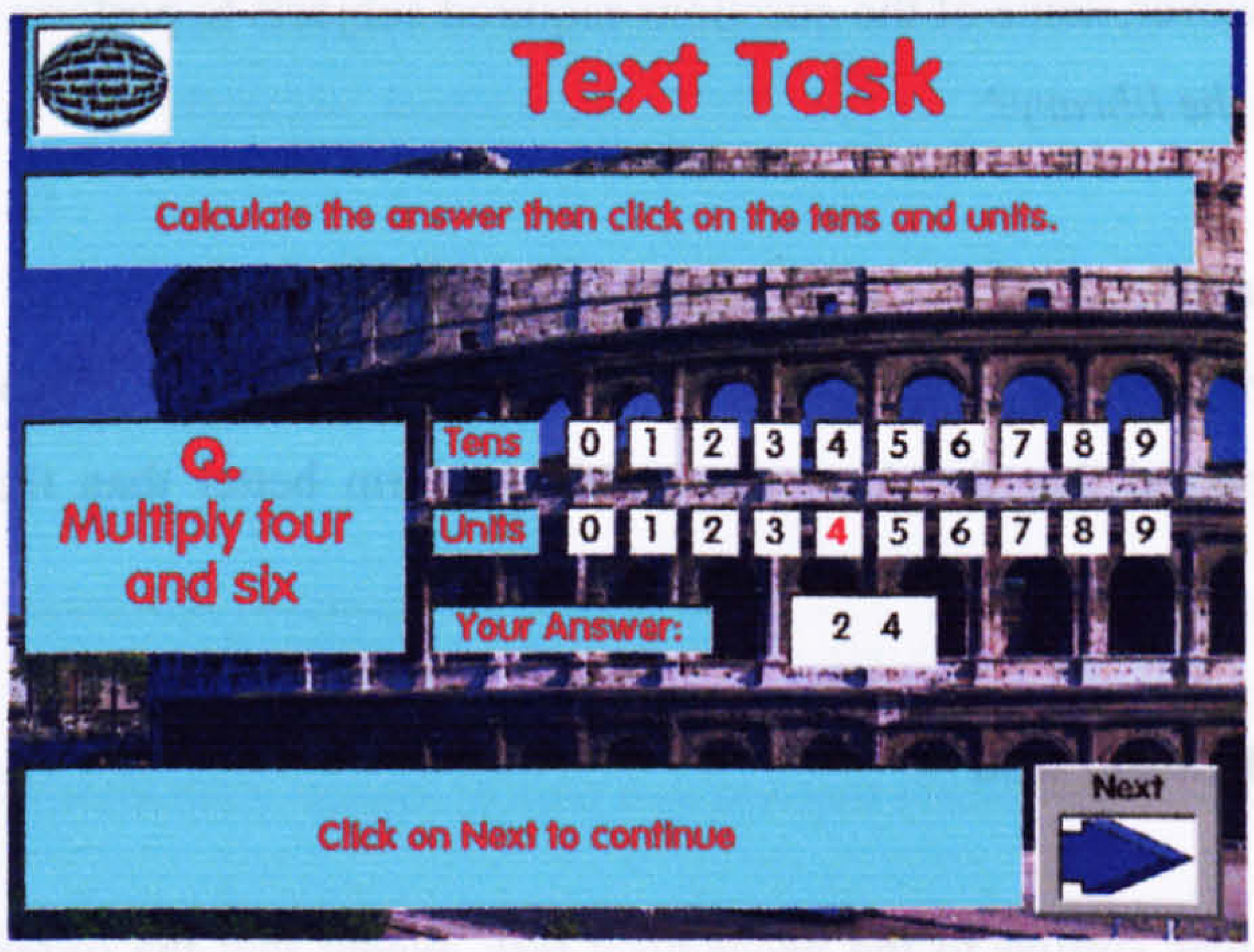


Figure 71: Text mathematics task interface

5.2.1.4 Text test procedural task

In the *procedural* task subjects answered questions on a set of directions.

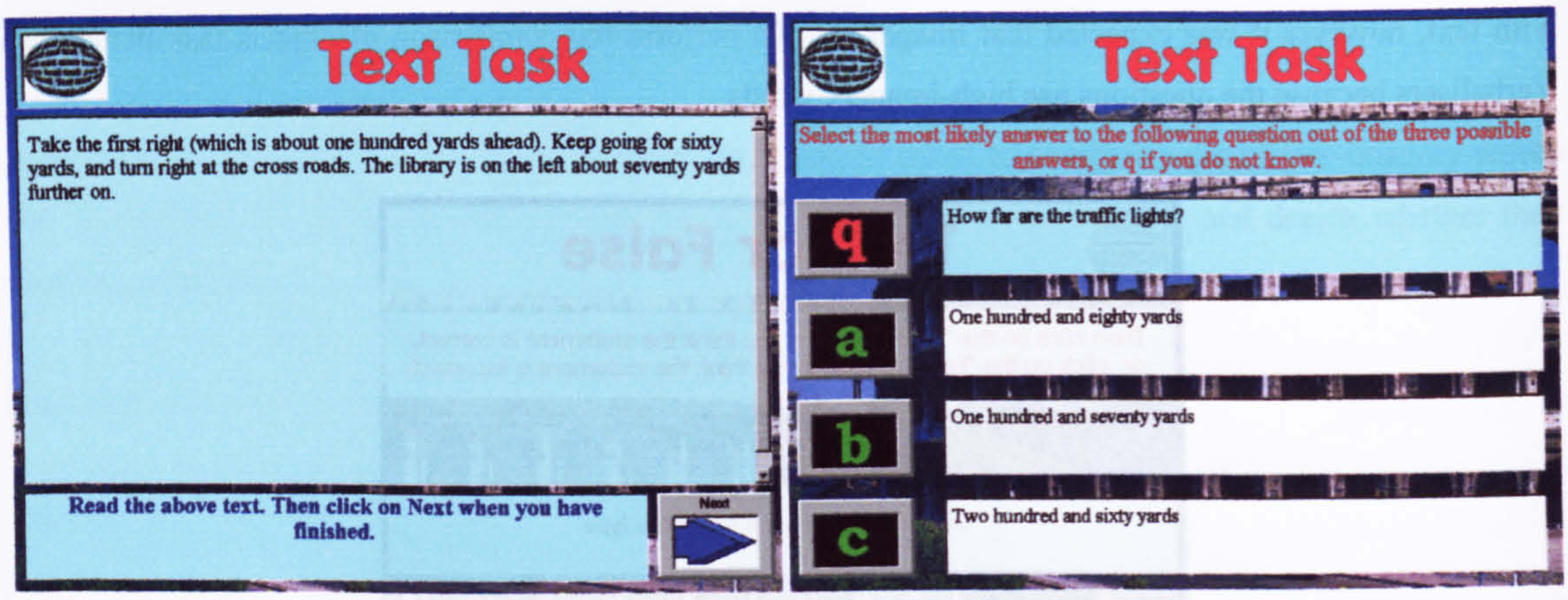


Figure 72: Text procedural task interface

First subjects read a set of procedural instructions such as the directions through the streets of a town (left image figure 72). Then subjects were asked a series of questions such as:

How Many times do you turn a left corner?

or

How Many times do you turn a right corner?

Subjects entered their answer by selecting one of three multiple-choice answers (right image figure 72).

As the task presented information using text it was expected that the Verbalisers would perform the *procedural* task better than Imagers (Riding, 1991; Riding, 1998). Also as the answers required subjects to recall the information in the order in which it was presented it was expected that Wholists would perform better than Analytics. However, some of the questions required subjects to perform calculations such as:

How far away is the library?

or

How far are the traffic lights?

For these questions the order in which the information was presented was less important than performing the calculation so it was expected that the Analytics would perform better than the Wholists (Riding, 1991; Riding & Rayner, 1998).

5.2.1.5 Text test comprehension task

The *comprehension* task was similar to the *procedural* task except that the order in which the information was presented was not the important factor. Subjects first read a short piece of text, including extracts of fiction and non fiction (left image figure 73) and then answered a series of multiple–choice questions (right image figure 73).

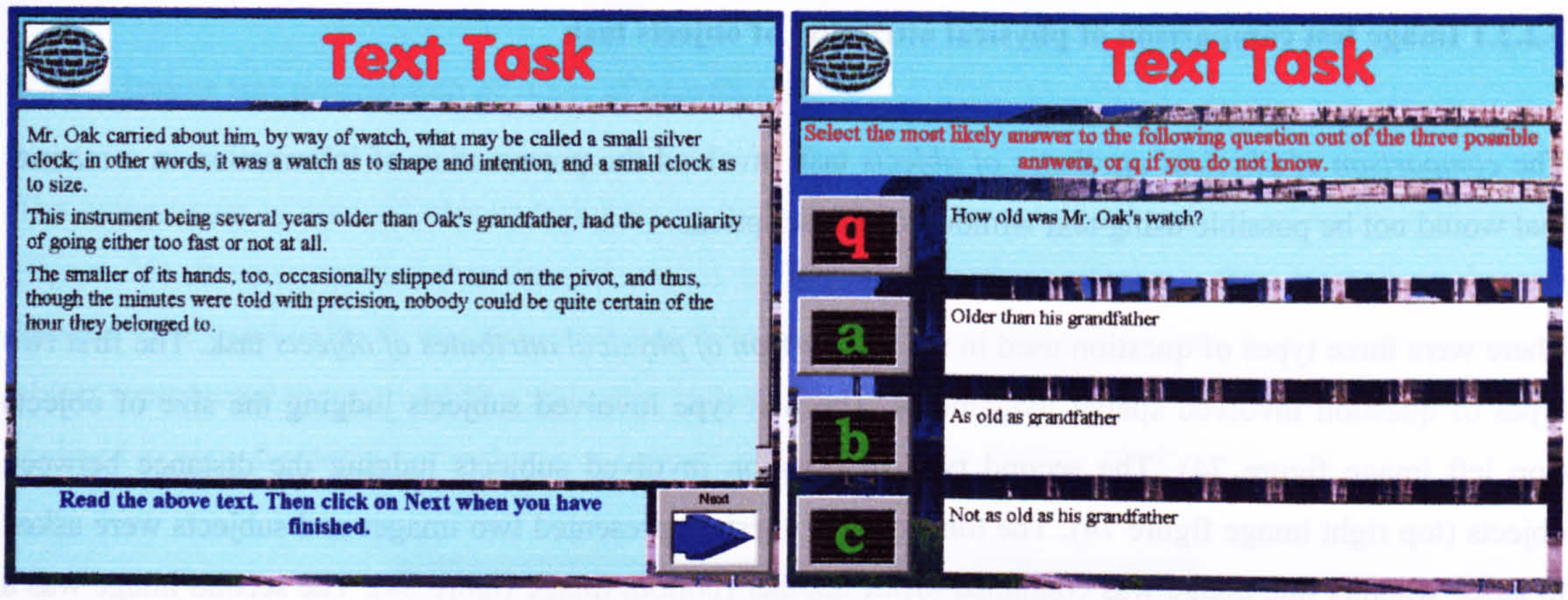


Figure 73: Text comprehension task interface

As the task presented information using text it was expected that the Verbalisers would perform the *comprehension* task better than the Imagers (Riding, 1991; Riding, 1998). Also it was expected that Analytics would perform the task better than Wholists as the questions were about the details of the information rather than the information as a whole.

All tasks were assessed to identify the features that favoured the performance of one category of CS. While some had features that favoured one category of Wholist-Analytic dimension or one category of the Verbal-Imagery dimension not all the tasks had features that favoured one category in both dimensions. Verbalisers were expected to perform better than Imagers in all the tasks that used text except the *comparison of objects* task that Imagers were expected to perform better. Wholists were expected to perform better than Analytics at the *procedural* task questions that did not include calculations, while Analytics were expected to perform better than Wholists at the *comprehension, mathematics* tasks and the *procedural* task questions that required calculations to be performed.

5.2.2 Design of the Image Test

The role of Images in a multimedia computer system is to present information using a spatial representation of an object. Images may be 2 or 3D representation and may be real (photographic) or virtual (diagrams). Like text the presentation of stationary images is time independent (Steinmetz & Nahrstedt, 1995).

The image test used a similar range of tasks to the text test, but there were differences that reflect the different nature of the media. While a purely verbal presentation is often possible an alternative purely pictorial version is not always an option and often some words are necessary (Riding & Ashmore, 1980; Riding & Watts, 1997). Therefore the image test presented images to the subjects with the minimum number of words required to indicate what was required for each task.

5.2.2.1 Image test comparison of physical attributes of objects task

The *comparison of physical attributes of objects* task involved the presentation of information in a manner that would not be possible using text without long descriptions.

There were three types of question used in the *comparison of physical attributes of objects* task. The first two types of question involved spatial judgements. The first type involved subjects judging the size of objects (top left image figure 74). The second type of question involved subjects judging the distance between objects (top right image figure 74). The third type of question presented two images and subjects were asked to judge whether one image was contained inside another (bottom image figure 74). The second image was a magnified section of the original image or a similar image. This type of question was similar to the Analytic questions used in the CSA test where subjects were asked to judge whether a simple graphic shape was contained in a more complex shape except these questions presented photographic images (Riding, 1991; Riding, 1998).

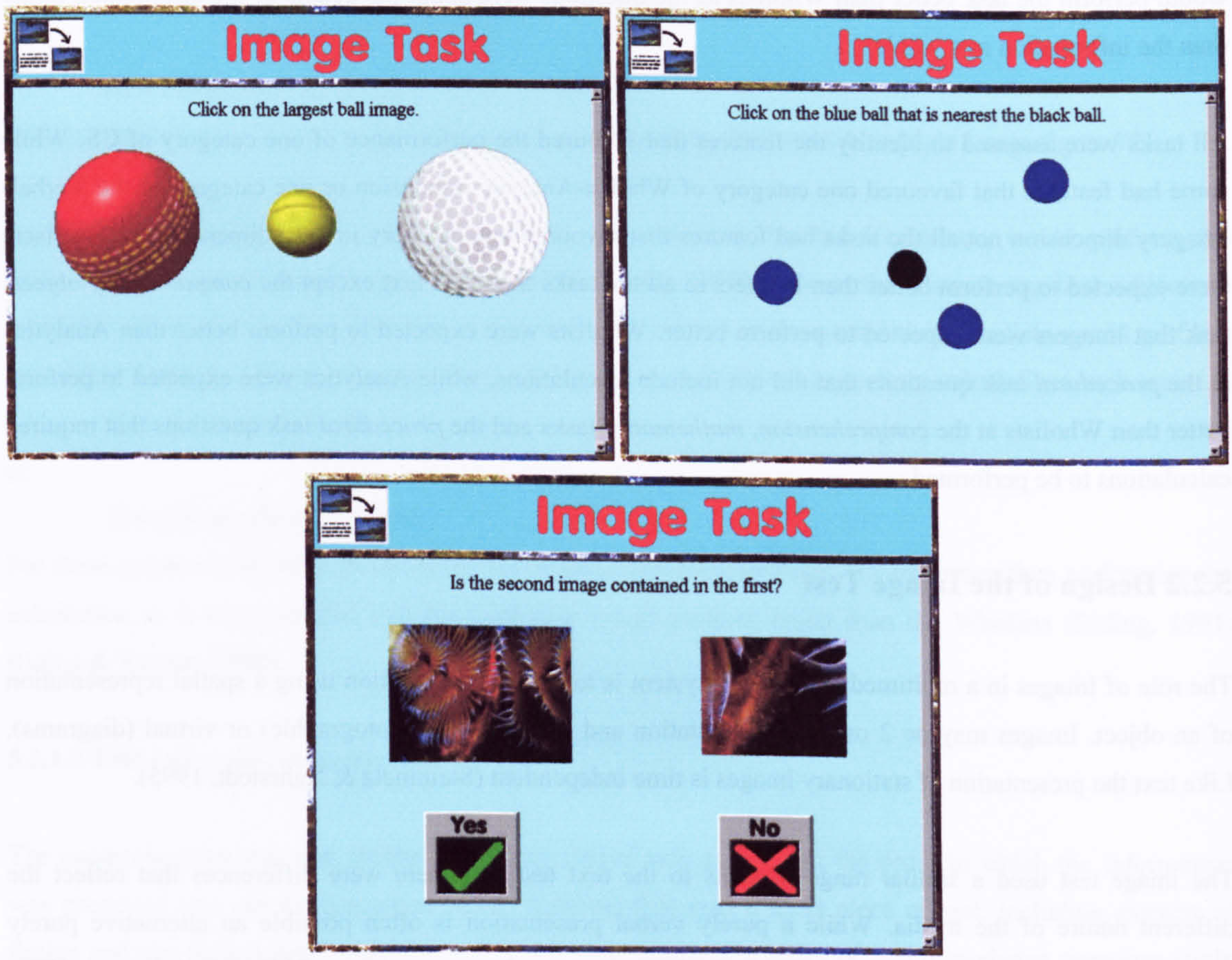


Figure 74: Image comparison of physical attributes of objects task interfaces

As information was presented using images it was expected that Verbalisers would perform the *comparison of physical attributes of objects* task better than Imagers. Also it was expected that Analytics would perform the task better than Wholists because the task required subjects to consider the components within an image.

5.2.2.2 Image test comparison of types of objects task

The *comparison of types of objects* task presented three objects and asked subjects to select the odd one out (figure 75). It was expected that the task would be performed better by Imagers than Verbalisers because images were used. Also it was expected that Wholists would perform better than Analytics because each object represented separate entities and subjects had to judge which matched while Analytics would be more inclined to view the details of each object separately (Riding, 1991; Riding, 1998).

Figure 75: Image comparison of types of objects task interface

5.2.2.3 Image test comparison of objects task

The image *comparison of objects* task was similar to the text *comparison of objects* task but instead of presenting two words, the images of two objects were presented. Instead of asking whether these objects were the same type subjects were asked whether the objects were the same. In the following example (figure 76) the objects were not the same because the mouth was closed in one and open in the other. This task was similar to the Wholist style questions in the CSA test (Riding, 1991; Riding, 1998) for which subjects were asked to determine whether two objects were identical. This task required subjects to make the same decisions but used more complex images of objects rather than simple geometric shapes.

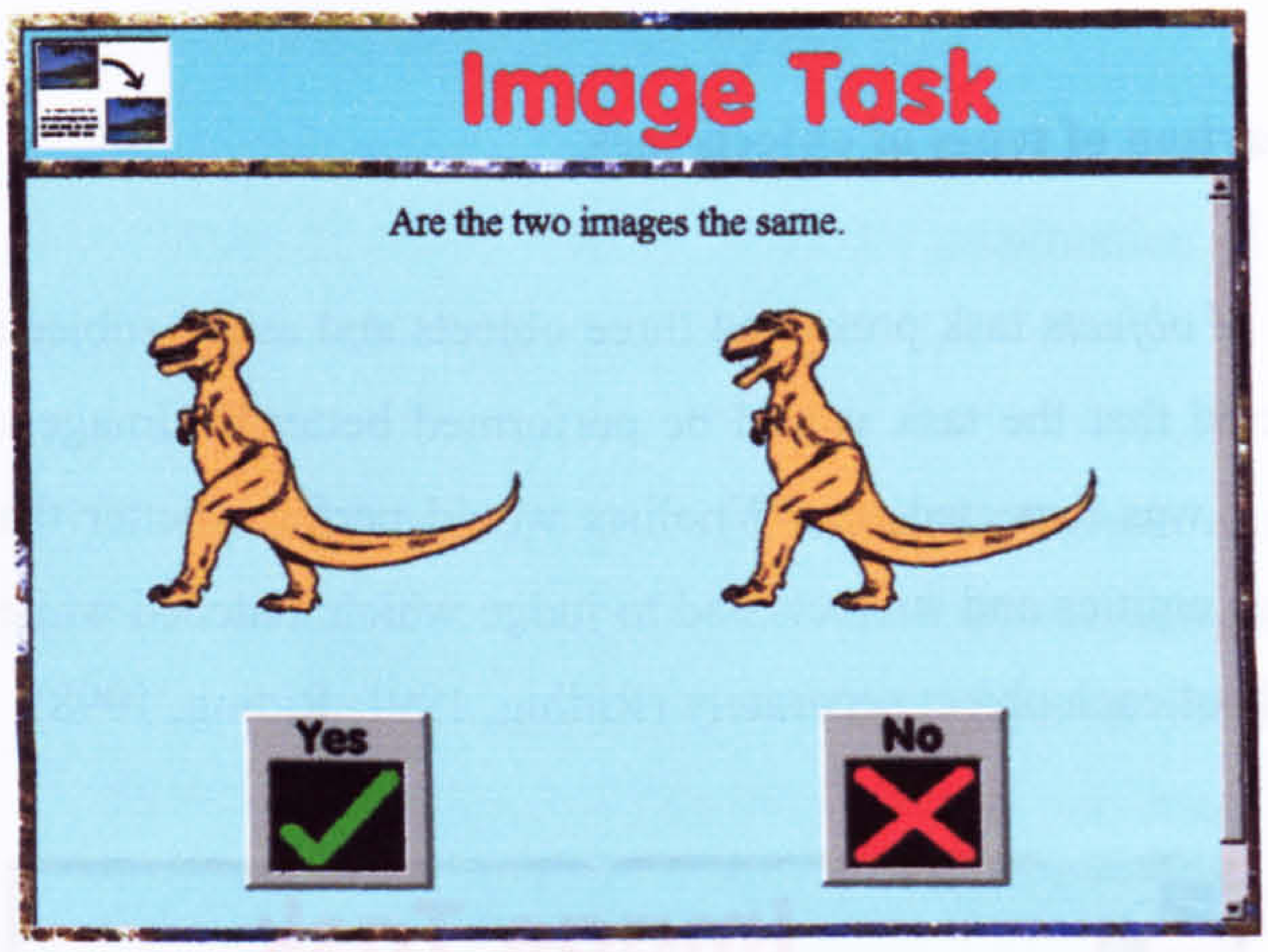


Figure 76: Image comparison of objects task interface

As images were used Imagers were expected to perform better than Verbalisers and as the questions were similar to the Wholist questions in the CSA test Wholists were expected to perform better than Analytics.

5.2.2.4 Image test configuration task

The image *configuration* task was similar to the text *procedural* task as it presented similar information such as the location of landmarks on a map (figure 77) however it contrasted with the text *procedural* task because an understanding of the map was not dependent on the order in which directions were given but instead subjects had to make sense of the spatial organisation themselves. Subjects studied the map for as long as they required and then they were asked a series of questions about how the landmarks related to each other, such as which landmark was nearest to another (right image figure 77).

Imagers were expected to perform better than Verbalisers at the *configuration* task because images were used, and Analytics were expected to perform better than Wholists because recall of the information did not depend on the order it was presented (Riding, 1991; Riding, 1998)

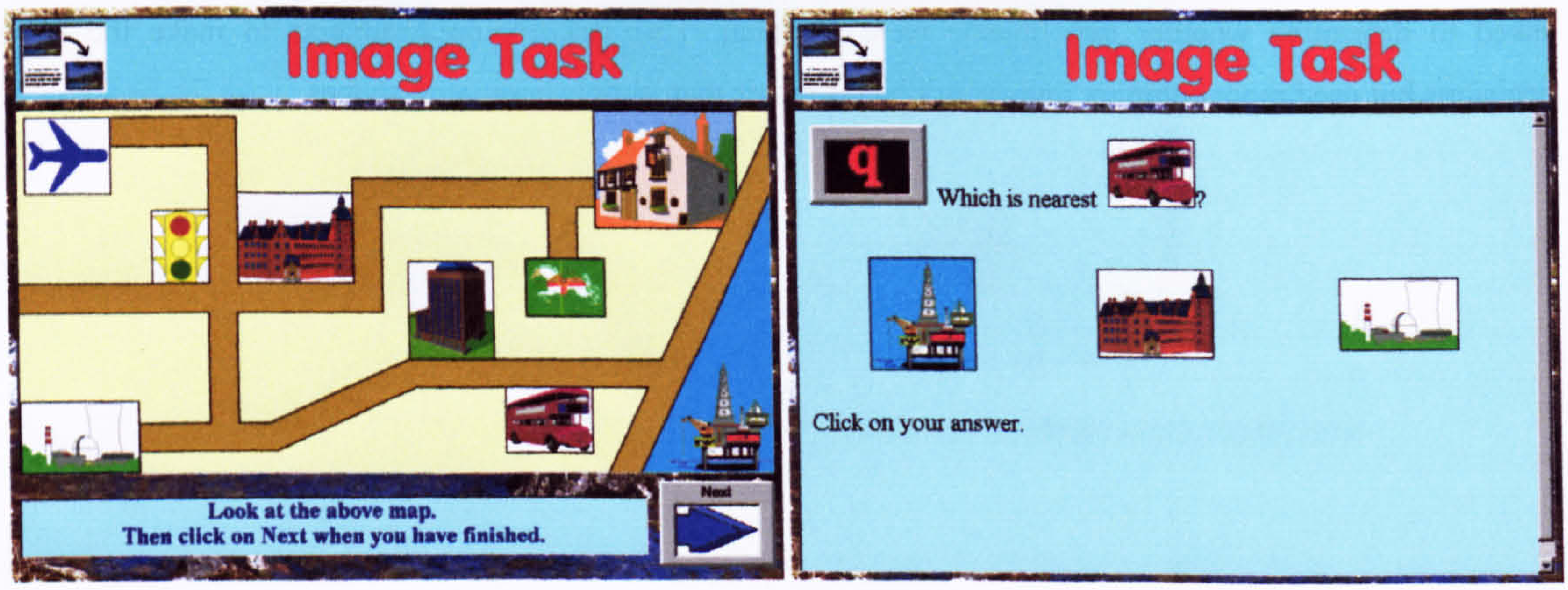


Figure 77: Image configuration task interface

5.2.2.5 Image test mathematics task

The image *mathematics* task was similar to the text *mathematics* task except the numbers were represented by images of dice and the symbols for addition, multiplication and division were used (figure 78). Instead of subjects entering their answer by clicking on tens and units, subjects clicked on one of three sets of dice that showed the correct answer. Verbalisers were expected to perform the *mathematics* task better than Imagers and Analytics would perform the task better than Wholists.

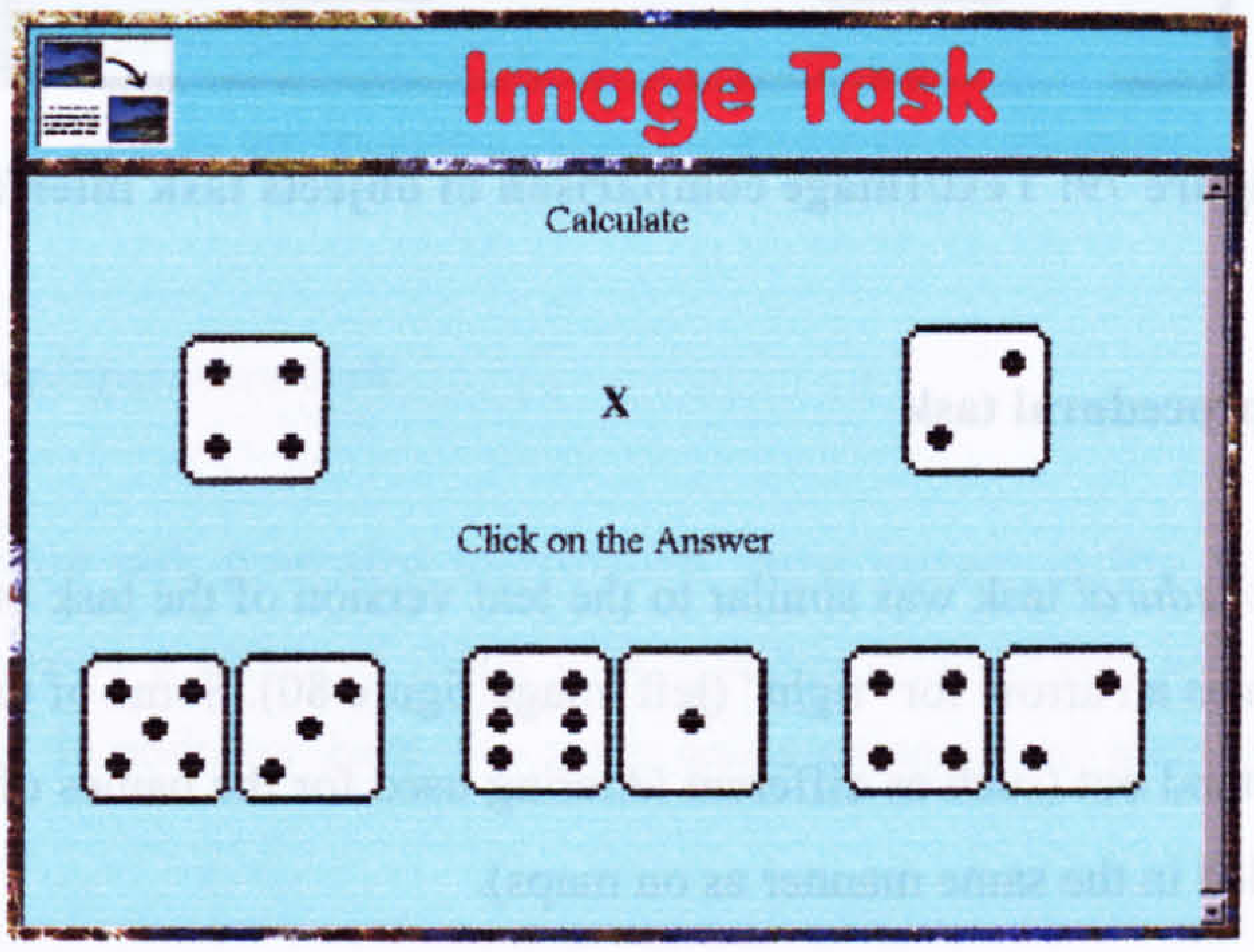


Figure 78: Image mathematics task interface

5.2.3 Design of the Text/Image Test

It was expected that, with a few exceptions, Verbalisers would perform better than Imagers in the text test and Imagers would perform better than Verbalisers in the image test. Therefore another test was designed to test the effect of presenting a combination of text and images.

5.2.3.1 Text/Image test comparison of objects task

The text/image *comparison of objects* task was similar to the text test *comparison of objects* task except the pairs of objects were represented by a mixture of images and words (figure 79). The pairs of objects were either alternate representations of the same object or were similar sorts of objects. Subjects were asked to determine whether the two objects were the same type, colour or size.

It was expected that Imagers would perform better than Verbalisers in this task because the task used high-imagery words and images (Riding, 1991; Riding, 1998).

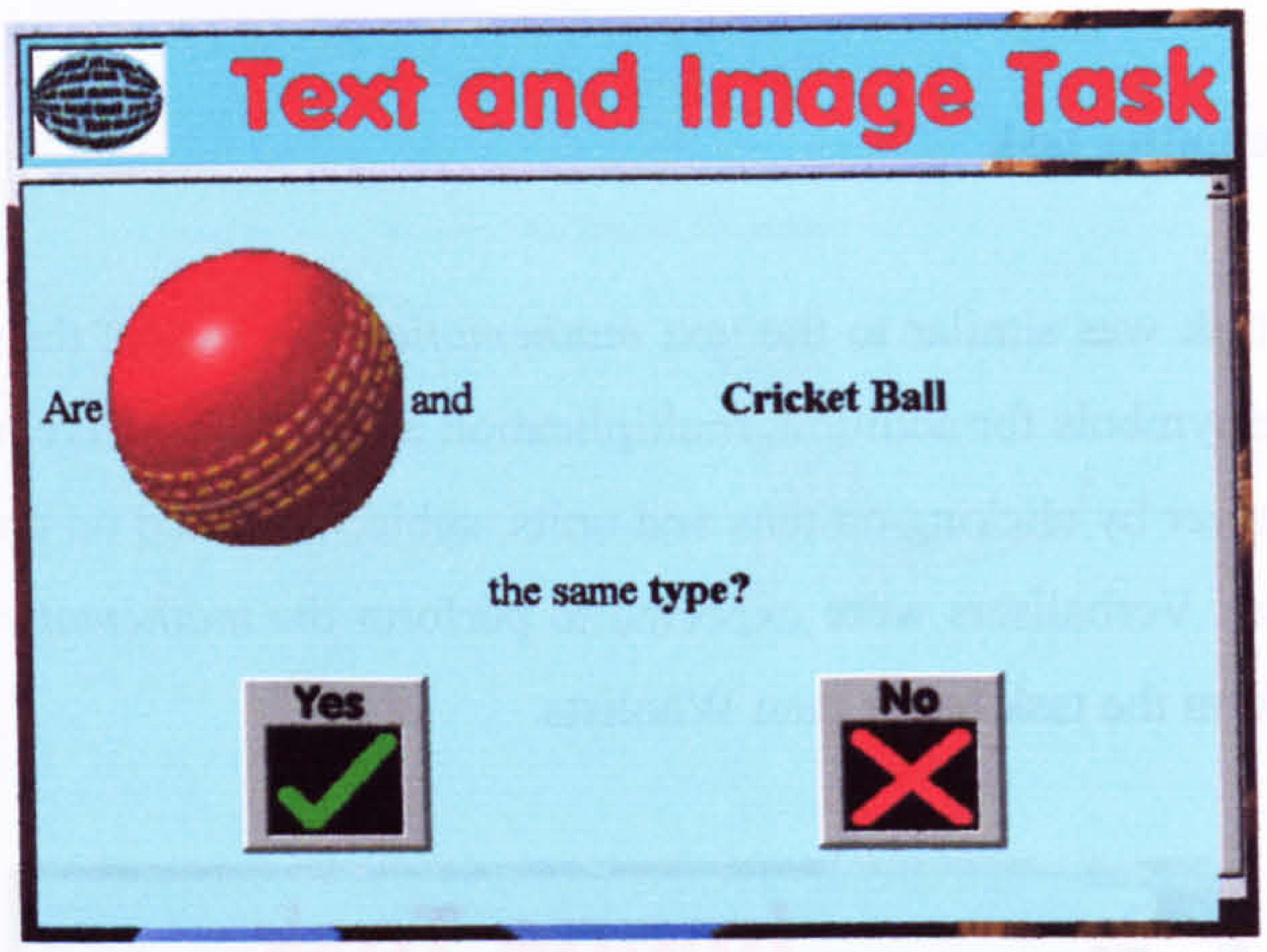


Figure 79: Text/Image comparison of objects task interface

5.2.3.2 Text/Image test procedural task

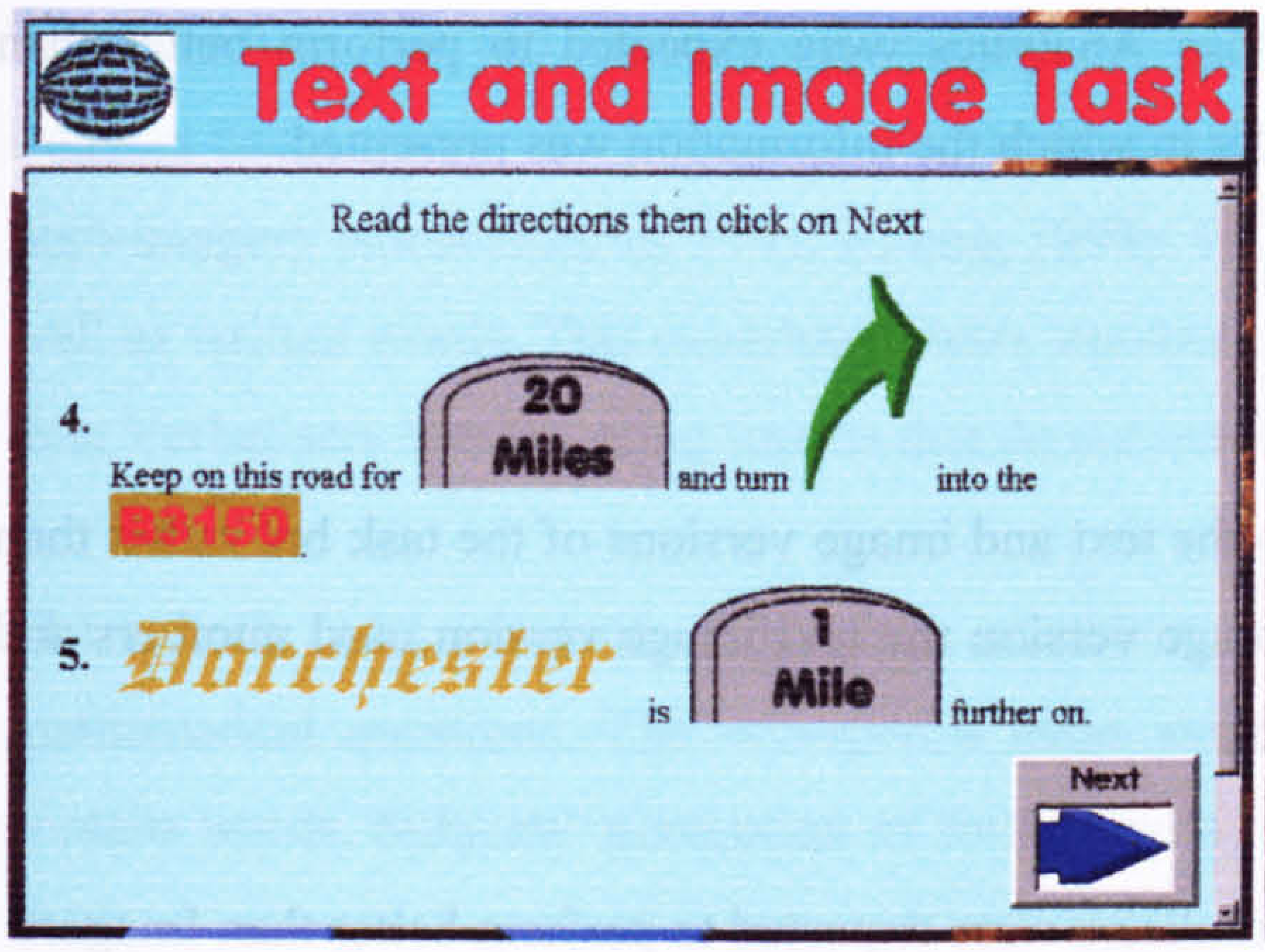
The text/image of the *procedural* task was similar to the text version of the task but some of the words were replaced by symbols such as an arrow for "right" (left image figure 80). Some of the words were decorated in a manner to make them stand out (such as different lettering used for the names of town, milestones used for distances and roads labelled in the same manner as on maps).

After viewing the *procedural* information at their own speed subjects were asked a series of multiple-choice questions such as:

Which road is nearest Dorchester?

Subjects entered their answers by selecting one of three images (right image figure 80).

On balance more text than images were used in the directions so it was expected that Verbalisers would perform better than Imagers, however the difference in performance between Verbalisers and Imagers would be lower than the version of the *procedural* task using just text. Wholists were also expected to perform better than Analytics in the questions for which the answers depended on the order in which information was presented, while Analytics were expected to perform better than Wholists in the questions that required subjects to perform calculations.



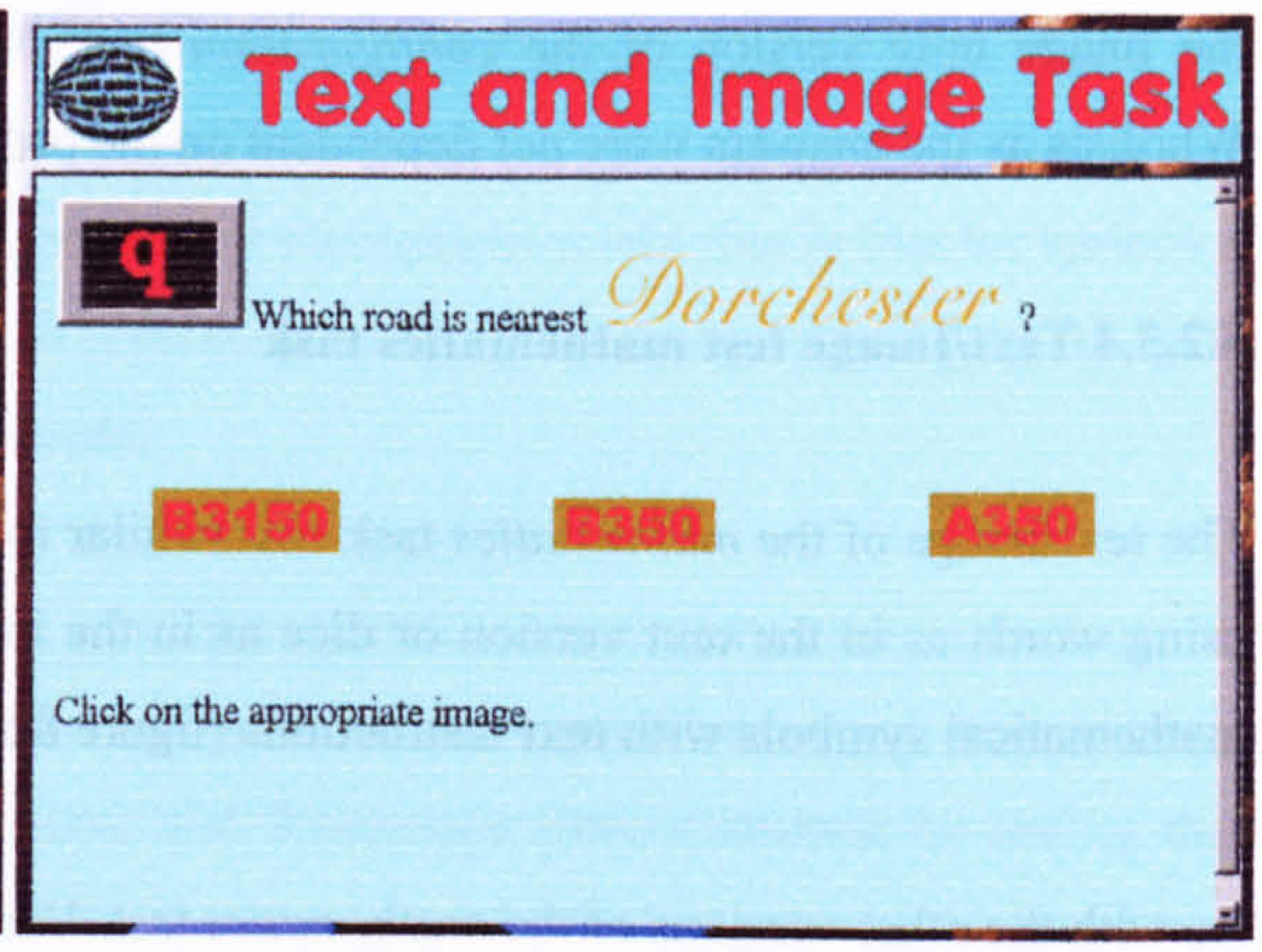


Figure 80: Text/Image procedural task interface

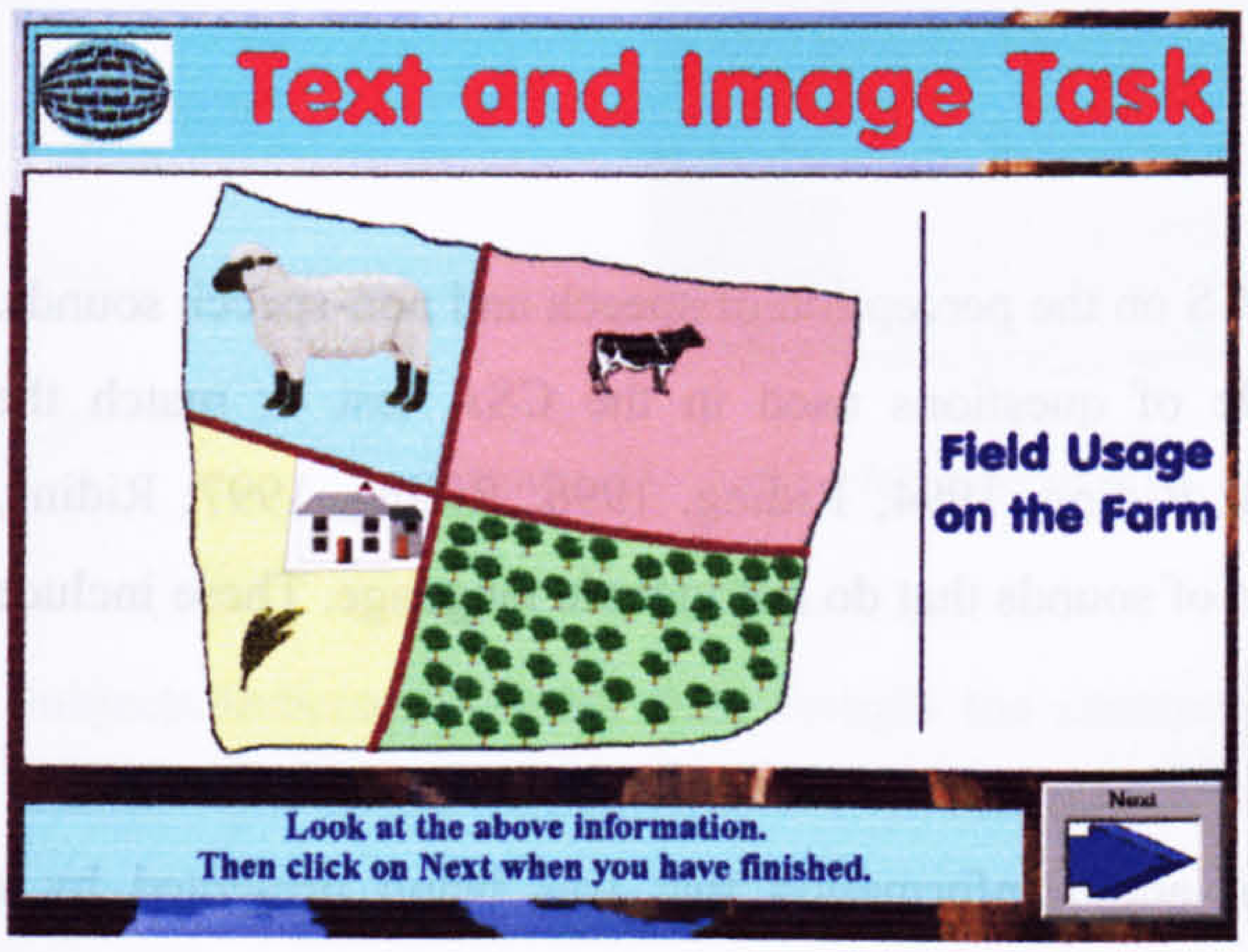
5.2.3.3 Text/Image test configuration task

The text/image *configuration* task presented information using images in the same manner as the Image *configuration* task. There were a series of maps with symbols representing information such as location, orientation and field usage. In addition there was some accompanying text about how to interpret the maps (left image figure 81).

After viewing the maps at their own pace subjects had to answer a series of multiple-choice questions such as:

Which farming activity takes most field space on the farm?

(right image figure 81).



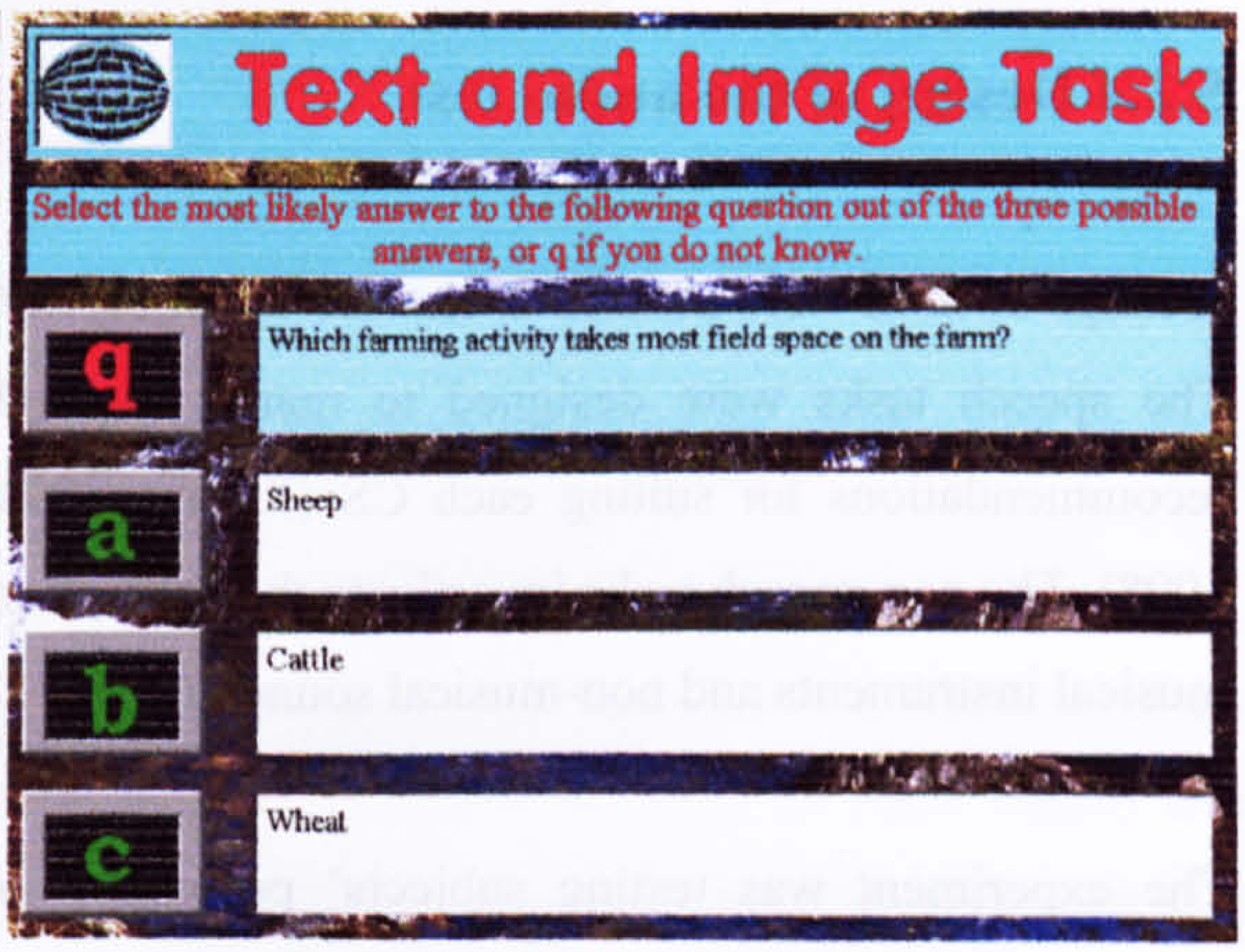


Figure 81: Text/Image configuration task interface

Like the image version of the *configuration* task Imagers were expected to perform better than Verbalisers but the difference in performance between the Imagers and Verbalisers was not expected to be as great as for the image only version of the *configuration* task. Also Analytics were expected to perform better than Wholists as the answers were not dependent on the order in which the information was presented.

5.2.3.4 Text/Image test mathematics task

The text/image of the *mathematics* task was similar to the text and image versions of the task but rather than using words as in the text version or dice as in the image version the text/image version used numbers and mathematical symbols with text instructions (figure 82).

As with the other versions of the *mathematics* task Verbalisers were expected to perform better than Imagers and Analytics were expected to perform better than Wholists.

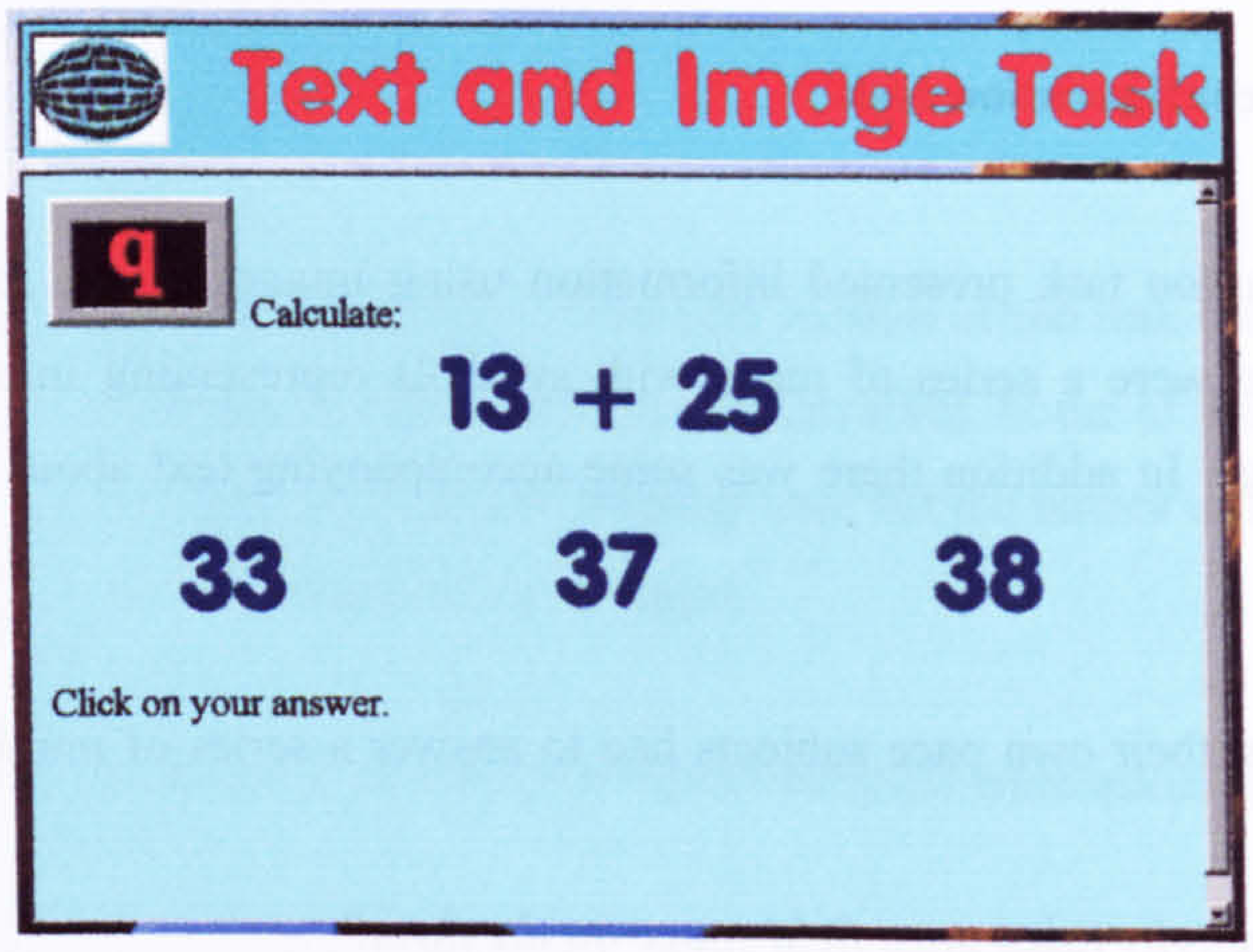


Figure 82: Text/Image mathematics task interface

5.2.4 Design of the audio test

A range of tasks were devised to explore the effect of CS on the perception of speech and non-speech sounds. The speech tasks were designed to match the style of questions used in the CSA test or match the recommendations for suiting each CS (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1997; Riding, 1998). The non-speech tasks investigate the perception of sounds that do not include language. These include musical instruments and non-musical sound effects.

The experiment was testing subjects' perception of audio information that was being presented by a multimedia computer system. Subjects were first presented with audio information and their understanding of the information was tested by asking a number of multiple-choice questions using a multimedia interface. Questions were asked using audio but subjects entered answers by clicking on the text or images that represented possible answers.

The CSA manuals and supporting literature indicates that in general Verbalisers will perform better than Imagers using words while Imagers would perform better than Verbalisers in tasks using words that contain high-imagery words (Riding, 1991; Riding, 1998). The audio test attempts to verify that is true for spoken as well as written words. This experiment tests whether the reverse is also true that Imagers will perform better than Verbalisers in tasks using sounds that do not use words.

The speech tasks involved comparison of objects or concepts questions, comprehension questions and mathematical questions. The non-speech tasks examined how individuals perceive sound that does not contain words. Subjects' perception of timbre, consonance and dissonance were examined by testing their ability to recognise musical instruments and sound effects. It was expected that Imagers would perform all the non-speech tasks better than Verbalisers because the tasks did not use words.

5.2.4.1 Audio test comparison of objects task

The *comparison of objects* task like the text version used high-imagery words such as 'mug' and 'cup' and subjects were asked to evaluate whether the two words were the same colour or type. Pre-recorded spoken statements were played, such as:

Daffodil and Canary are the same colour

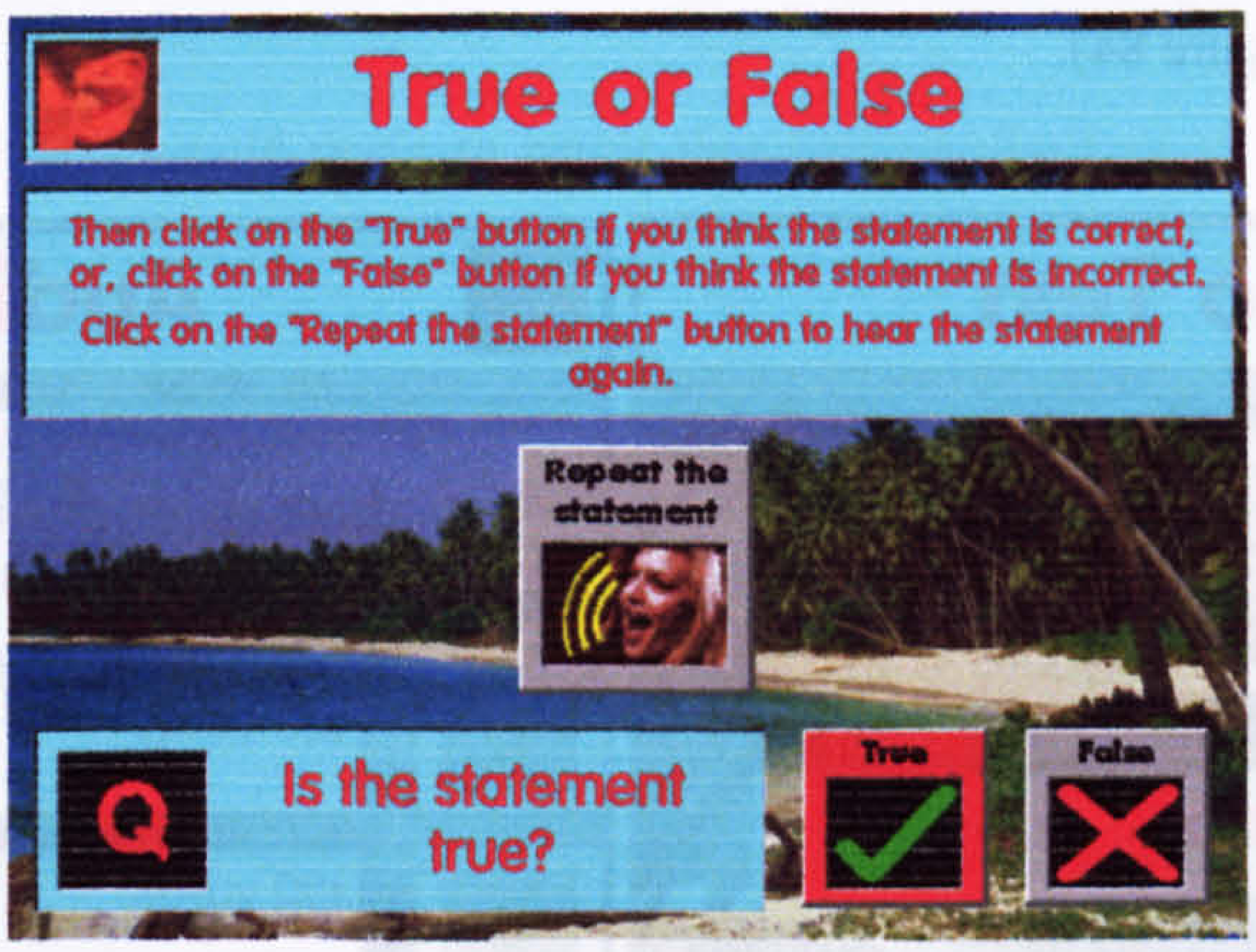


Figure 83: Audio comparison of objects and concepts tasks interface

Subjects indicated whether they thought the statement was true or false by clicking on the buttons on the bottom right of the screen (figure 83). The time it took subjects to choose the *True* or *False* button was recorded and not the time taken to play each statement unless they chose to listen to the statement again (by clicking on the *Repeat the statement* button).

A trial version of the experiment used a text-to-speech application to read the statements but the effort required by subjects to recognise the words was found to be too distracting and so the statements were recorded using a human voice.

As a general rule it was expected that Verbalisers would perform better at the tasks that use words than Imagers, however it was expected that Imagers would perform this task better than Verbalisers because the words used such as *daffodil* and *canary* could be visualised as objects (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1997; Riding, 1998).

5.2.4.2 Audio test comparison of concepts task

The *comparison of concepts* task was similar to the *comparison of objects* task but used words that do not form images in the minds of people such as *Rugby* and *Tennis*. This task used the same interface as the *comparison of objects* task (figure 83).

It was expected that Verbalisers would perform this task better than Imagers because the words used could not be visualised as objects (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1997; Riding, 1998).

5.2.4.3 Audio test procedural task

The *procedural* task tested subjects' recall and understanding of information presented in a procedural manner. Subjects were first presented with a set of procedural instructions, such as directions and distances between landmarks in a town (left image figure 84), and were then asked multiple-choice questions on the information (right image figure 84).

Figure 84: Audio procedural task interface

Like the text version of the task the procedural information contained directions and distances between landmarks in a town but the information was presented using pre-recorded speech rather than text. The task involved subjects recalling the information in the order it was presented, such as the order in which landmarks were mentioned or to calculate distances between landmarks. Using the information that did not contain distances subjects were asked to identify the order in which landmarks were reached with *true* or *false* questions such as:

The zebra crossing lies between the supermarket and the train station.

Using the information that contained distances subjects had to make calculations such as:

How far is the Post Office?

Answers were entered by clicking on one of three possible answers (right image figure 84).

Wholists store information serially while Analytics attach new pieces of information to information that they already know (Riding, 1991) therefore it was expected that Wholists would perform the *procedural* task questions that did not include calculations better than Analytics while Analytics would perform the *procedural* task questions that included calculations better than Wholists. It was also expected that Verbalisers would perform better than Imagers because the task involved the use of words (Riding, 1991; Riding, 1994; Riding, 1996; Riding, 1997; Riding, 1998).

5.2.4.4 Audio test mathematics task

The *mathematics* task involved subjects performing simple addition, multiplication and division calculations such as:

Multiply three and seven

A pre-recorded question was first read out and subjects had to compute the answer and enter the answer by selecting the appropriate numbers in the tens and units rows using a similar interface as used in the text test (figure 85).

It was expected that Verbalisers would perform better than Imagers because the task involved performing calculations and that Analytics would perform the computation quicker than Wholists (Riding, 1991).

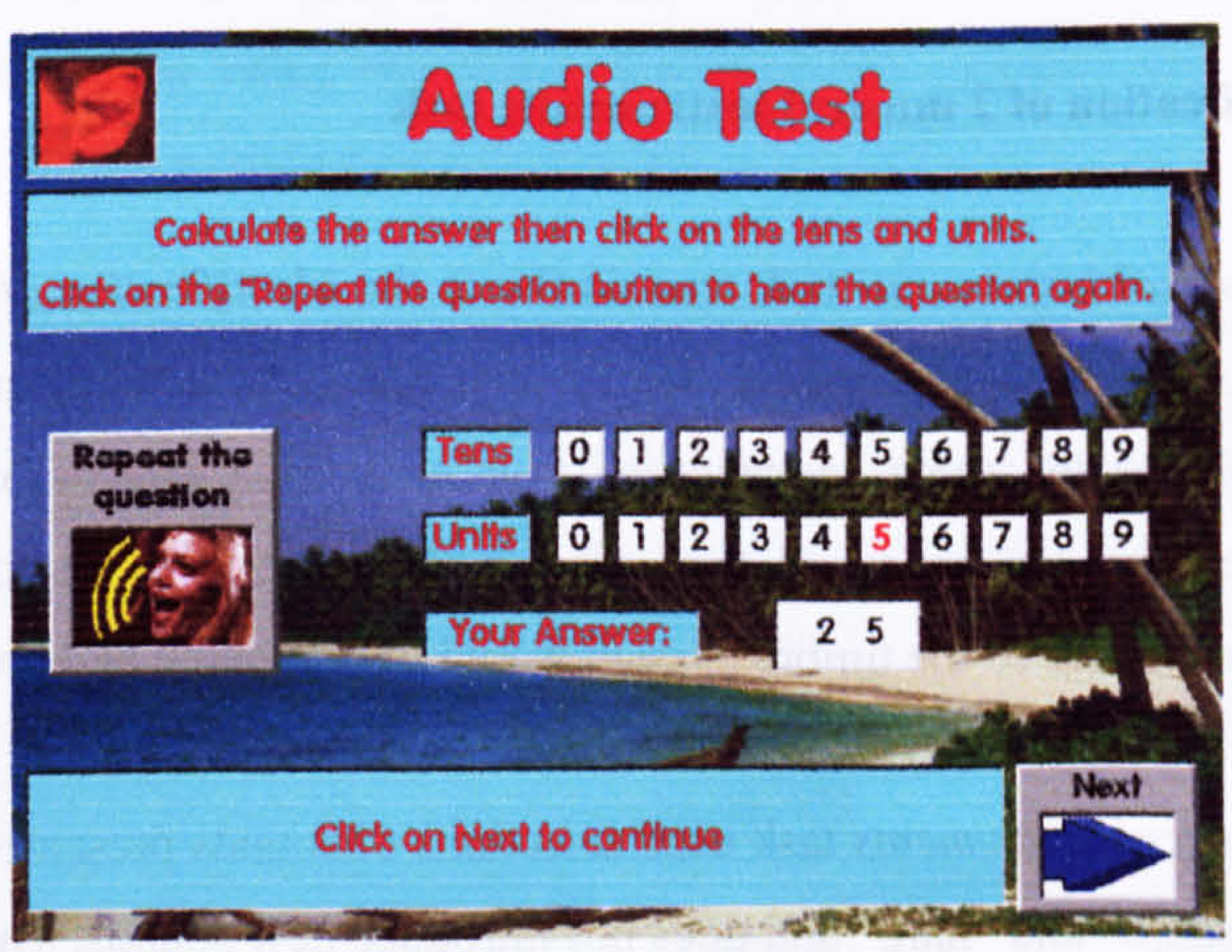


Figure 85: Audio mathematics task interface

5.2.4.5 Audio test identification of 1 musical instrument task

Figure 86: Instrument recognition task interface

In the *identification of 1 musical instrument* task subjects were played groups of three similar sounding musical instruments with consistent pitch, loudness and location. The musical ability or experience of subjects was not being tested and so individual notes were played rather than melodies and the task used synthesised sounds that were associated with a label rather than real instruments (left image figure 86). First groups of instruments were played individually, then subjects were asked to identify individual instruments by clicking on the appropriate label (right image figure 86). Instruments were presented individually in groups of three similar sounding instruments and were followed by two questions before the next group were displayed.

5.2.4.6 Audio test identification of 2 musical instruments task

The *identification of 2 musical instruments* task was similar to the *identification of 1 musical instrument* task but there was the added distraction of having to distinguish between two instruments playing at the same time. Each instrument played the same sequence of four notes at a rate of one note per second. One instrument started playing the sequence and then after half a second the second started playing. Both instruments played the same notes so the timbre of each would be compared and not the difference in pitch.

The *identification of 2 musical instruments* task used selections of sounds presented in the *identification of 1 instrument* task such as "banjo" and "harp" and does not introduce new sounds. The same interface was used for subjects to enter answers as in the *identification of 1 instrument* task (right image figure 86)

5.2.4.7 Audio test identification of sound effects

The *identification of sound effects* task played a sound effect such as dog barking, a creaking door or a thunder clap. Subjects were asked to identify the sound by clicking on one of three images that represents the source of the sound. In the case of the sound of a dog barking subjects had to choose between images of a dog, a wolf or bear (figure 87).

Figure 87: Identification of sound effects task interface

5.2.5 Design of the Video test

Like audio, video is a continuous media and the presentation of information is time dependent (Steinmetz & Nahrstedt, 1995). The sequences used in the video test included text captions, still images, animated images, live action, speech, sound effects and music. Each task in the test consisted of a number of short video clips (less than a minute in length). Subjects were provided with a start button but had no other control over the flow of information. The video was displayed embedded in the interface and not within a separate window (left image figure 88). When the video clip finished playing the interface automatically changed to the multiple-choice questions interface (right image figure 88).

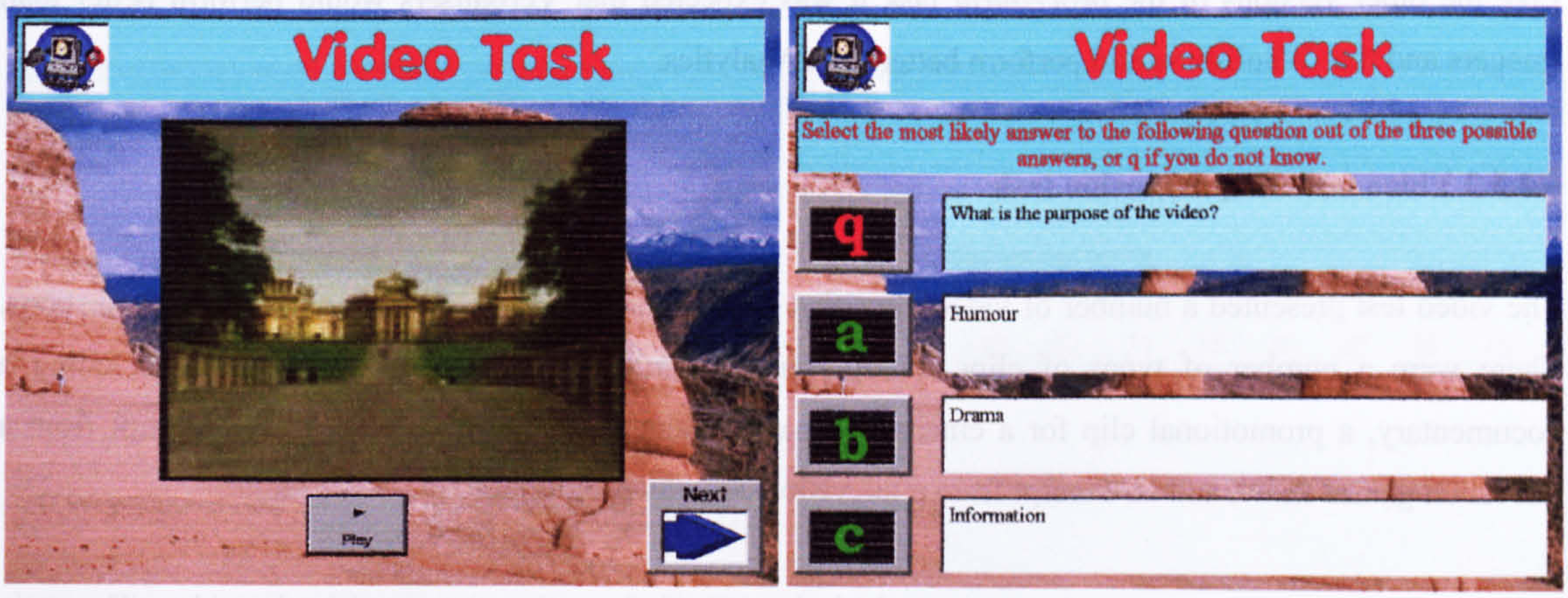


Figure 88: Video test interface

5.2.5.1 Video test procedural task

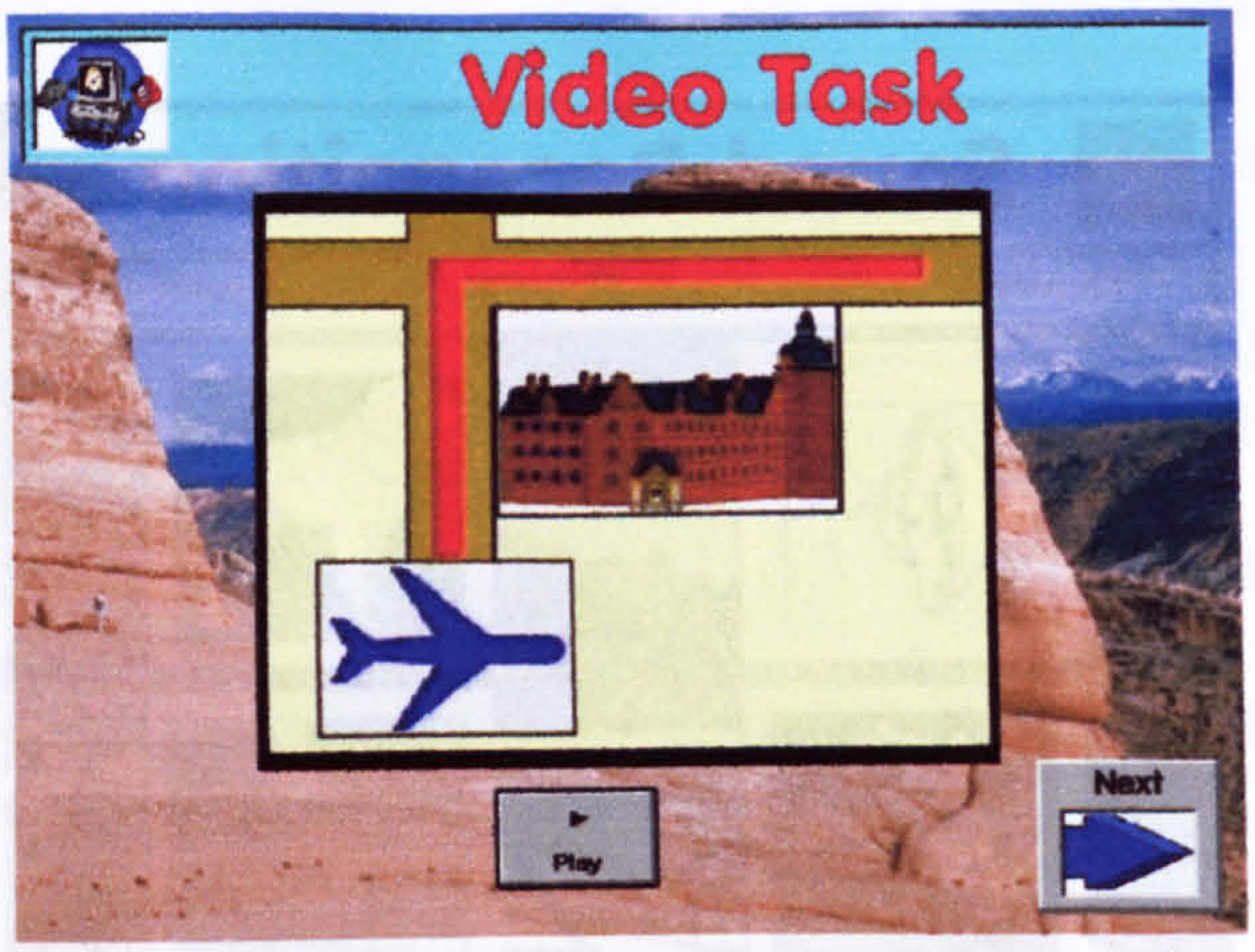


Figure 89: Video procedural task interface

The video version of the *procedural* task attempted to combine the audio *procedural* and image *configuration* tasks. A spoken soundtrack giving procedural directions was combined with images of the relevant sections of a map (figure 89). The video more closely resembled the *procedural* task rather than the *configuration* task because an understanding of the information depended on the order it was presented and the whole map was not shown.

The answers to the series of multiple-choice questions asked were dependent on the order in which the information was presented, such as:

Which building was reached first?

Like the other versions of the *procedural* task it was expected that Verbalisers would perform better than Imagers and that Wholists would perform better than Analytics.

5.2.5.2 Video test comprehension task

The video test presented a number of video clips that formed the basis of a set of comprehension questions. There were a number of types of clips to represent a number of different uses of video including a documentary, a promotional clip for a cinema drama, an animation of morphing faces, an excerpt from a television games show, and an excerpt from a television comedy programme.

A series of multiple-choice questions were asked about the information presented in the video. The main distinction between the questions were the detailed *comprehension* questions that asked subjects to recall specific details presented in the video clip and general *comprehension* questions about the nature of the video. The general *comprehension* questions included questions about the overall video clip such as

What is the purpose of the video?

and

What is the atmosphere of the video?

It was expected that Wholists would perform the general *comprehension* questions better than Imagers because they were concerned with the overall situation of the video clip, while it was expected that Analytics would perform the detailed *comprehension* questions better than Wholists because they were concerned with details of non-procedural information.

The detailed comprehension questions were further divided between questions that were based on observations of the audio or images used in the video clip. Questions that were based on visual observations include questions such as:

The camera zooms in on which feature?

Questions that were based on audio information included questions such as:

What sound alerts the pursuers?

It was expected that these questions would be performed better by Imagers than Verbalisers as they involved observations of information presented without the use of words (speech or text).

Questions that were based on the words used in the videos included questions based on the speech and text captions. Questions that were based on information presented by speech included questions such as:

What is the first reason that a drink is required?

Questions that were based on the text displayed in the video included questions such as:

Did the caption match the narration?

It was expected that Verbalisers would perform these questions better than Imagers because they were based on words (speech and text).

5.2.5.3 Video test mathematics task

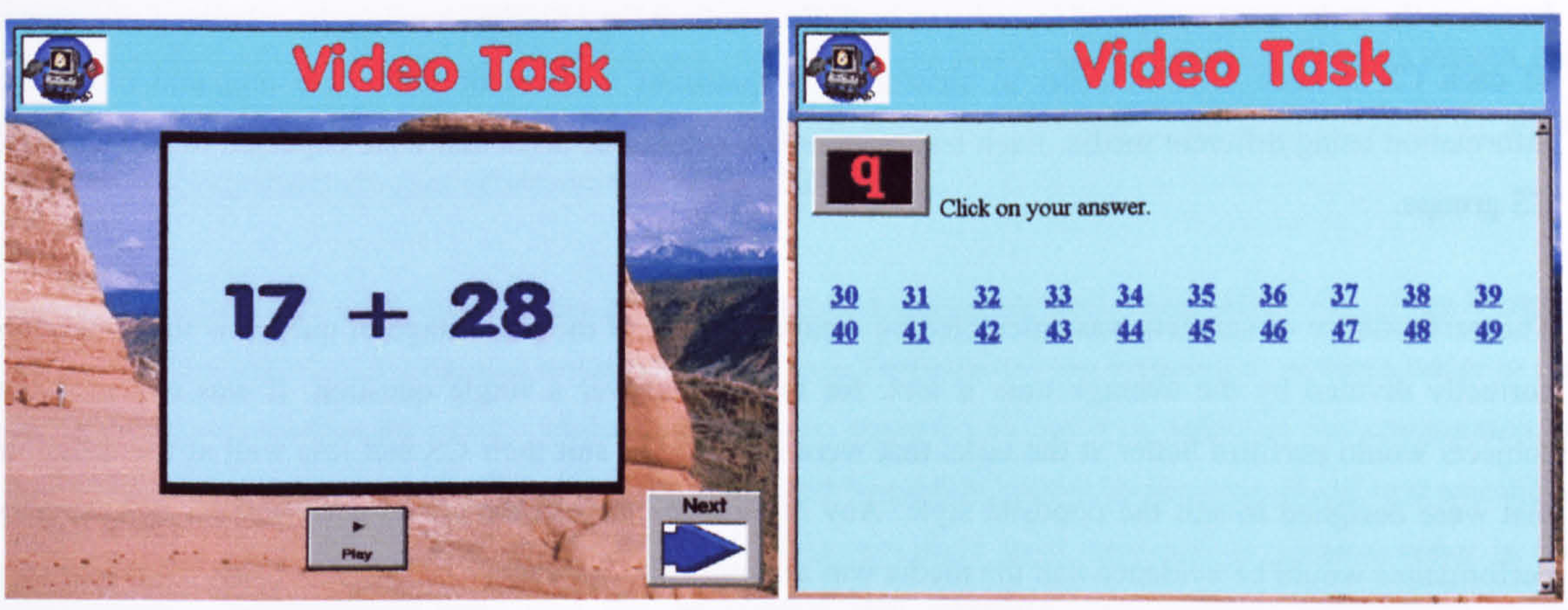


Figure 90: Video mathematics task interface

The video *mathematics* task was similar to the audio and video version of the task as the video version combined an audio soundtrack with images displaying the number and mathematical symbols synchronised with the audio soundtrack, ending with an image displaying the whole of the required addition, multiplication or division calculation (left image figure 90). Subjects had to remember the required calculation, perform the calculation in their head and enter their answer by selecting the appropriate number from a list of twenty possible numbers (right image figure 90).

Like the other versions of the *mathematics* task Verbalisers were expected to perform the task better than Imagers, and Analytics were expected to perform the task better than Wholists (Riding & Rayner, 1998).

5.3 Summary

This chapter discussed the design of an experiment that examined the effect that CS had on the performance of tasks where information was presented using different media. The way different media that are presented by multimedia computer systems are perceived were considered in order to plan the experiment. Different media are received in different parts of the brain and while some types of information are processed in media specific parts other information is processed in media non-specific parts.

There were two main questions that the experiment was designed to answer. The first question was whether CS affects the performance of users in the same manner when information is presented using different media. The second question was what types of tasks do the CS groups perform best using each type of media.

The tasks were designed to contain aspects that were expected to be suitable for different CSs and so any difference between the expected performance and actual performance among the media tests would indicate that the influence CS has on performance was dependent on the media that was presented. In order to answer the second question of which tasks were performed better by each CS group the relative performance between the tasks were compared in order to compile a ranked list of tasks showing the relative performance of each CS in each task. In order to answer these questions a series of tests were prepared presenting information using different media. Each test contained a number of tasks that were expected to suit different CS groups.

The performance of subjects was calculated by creating a ratio of the percentage of questions they answered correctly divided by the average time it took for them to answer a single question. It was expected that subjects would perform better at the tasks that were designed to suit their CS and less well at the questions that were designed to suit the opposite style. Any difference between the actual performance and expected performance would be evidence that the media was affecting performance.

The tasks that each CS group were expected to perform better in the text task are summarised in figure 91. The expected performance of Wholists is compared against Analytics and the expected performance of Verbalisers is compared against Imagers.

Wholists Procedural (that do not include calculations)	**Analytic** Comprehension Mathematics Procedural (that include calculations)
Verbaliser Comparison of Concepts Procedural Comprehension Mathematics	**Imager** Comparison of Objects

Figure 91: Text tasks the cognitive style groups were expected to perform best

Wholists Comparison of types of objects	**Analytic** Comparison of objects Comparison of physical attributes of objects Configuration Mathematics
Verbaliser Mathematics	**Imager** Comparison of objects Comparison of types of objects Comparison of physical attributes of objects Configuration

Figure 92: Cognitive style of image test tasks

In the image task it was expected that Imagers would perform better than Imagers in all tasks except the *mathematics* task. Similarly it was expected that Analytics would perform better than Wholists in all the tasks except the *comparison of types of objects* task (figure 92).

In the text/image task there was a wider spread of tasks that were expected to suit either side of the Verbal-Imagery dimension than for the text test or the image test. Verbalisers were expected to perform better in the *procedural* and *mathematics* tasks while Imagers were expected to perform better in the *comparison of objects* and *configuration* tasks. Wholists were expected to perform better in the *procedural* task questions that did not require calculations to be performed while Analytics were expected to perform better in the *mathematics*, *configuration* tasks and the *procedural* task questions that required calculations to be performed (figure 93).

Wholists Procedural (that do not include calculations)	**Analytic** Procedural (that include calculations) Mathematics Configuration
Verbaliser Procedural Mathematics	**Imager** Comparison of Objects Configuration

Figure 93: Text/Image tasks the cognitive style groups were expected to perform best

In the audio test the Verbalisers were expected to perform better than Imagers in all the tasks that used speech except the *comparison of objects* task. In addition Images were expected to perform better than Verbalisers in all the non-speech tasks. Wholists were expected to perform the *procedural* task questions that did not require calculations to be performed better than the Analytics while the Analytics were expected to perform the *mathematics* and *procedural* task questions that required calculations to be performed better than the Wholists. It was not known whether Wholists or Analytics would perform the non-speech tasks better than each other (figure 94).

Wholists Procedural (that do not include calculations)	**Analytic** Mathematics Procedural (that include calculations)
Verbaliser Comparison of Concepts Procedural Mathematics	**Imager** Comparison of Objects Identification of 1 musical instrument Identification of 2 musical instruments Identification of sound effects

Figure 94: Audio tasks the cognitive style groups were expected to perform best

In the video test Wholists were expected to perform the *procedural* and general *comprehension* task questions better than the Analytics. Analytics were expected to perform the *mathematics* and detailed *comprehension* task questions better than Wholists. Verbalisers were expected to perform the *mathematics* and the word-based *comprehension* tasks better than Imagers. Imagers were expected to perform the non-word-based *comprehension* task questions better than Verbalisers (figure 95).

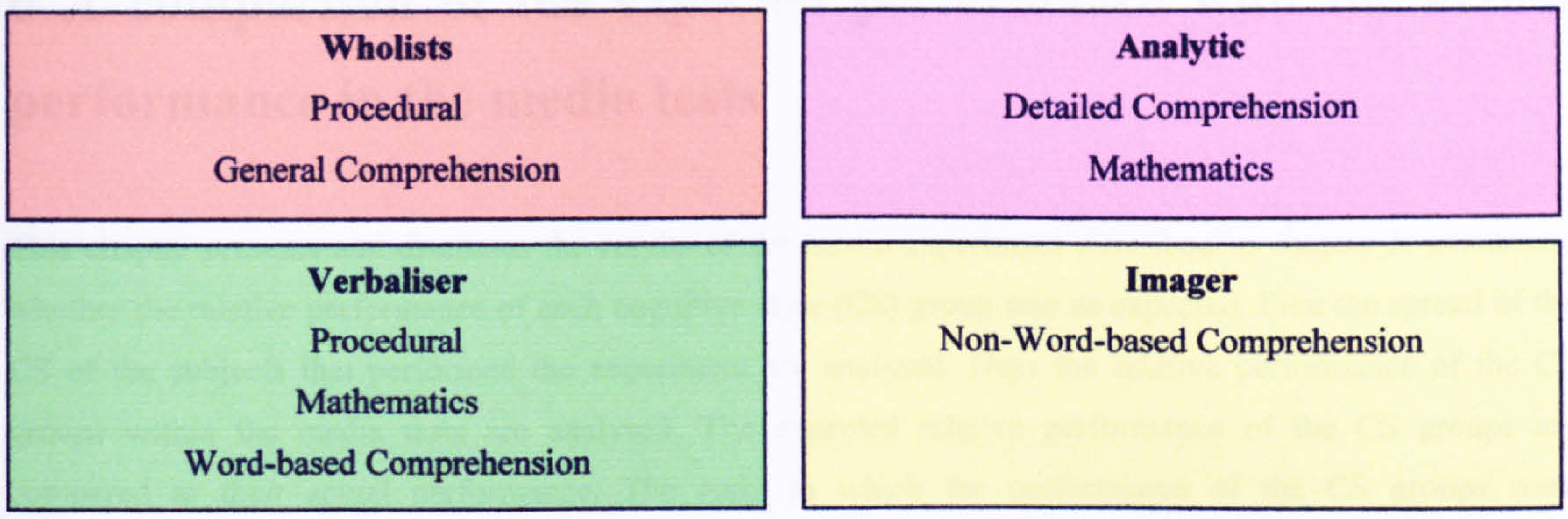


Figure 95: Video tasks the cognitive style groups were expected to perform best

A full list of all questions used in each test is given between Appendix 4 and 8. The results of each test are discussed in the next chapter.

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6 A comparison of the expected performance with the actual performance in the media tests

This chapter presents and discusses the results of the media experiment described in chapter 5, examining whether the relative performance of each cognitive style (CS) group was as expected. First the spread of the CS of the subjects that performed the experiment are analysed. Next the relative performance of the CS groups within the media tests are analysed. The expected relative performance of the CS groups are compared to their actual performance. The tasks in which the performance of the CS groups were significantly different are identified. The hypothesis that was developed in chapter 5 is tested to determine whether:

- A persons' cognitive style will affect their performance in a predictable manner when performing tasks that use the same media that are used in the CSA.
- A persons' cognitive style will affect their performance in a predictable manner when processing information using the same parts of the brain that were used during the CSA test.

6.1 Cognitive style of subjects

The CS of the fifty subjects who undertook the experiments was assessed using the CSA test. Table 26 summarises the number of subjects in each CS group. As in the first experiment (chapter 4) each dimension is divided at the mid point of the intermediate and bimodal sections.

Cognitive Style	Verbaliser	Imager	Total
Wholist	10	13	23
Analytic	11	16	27
Total	21	29	50

Table 26: Subject numbers for each cognitive style group

There was a fairly even division of subjects between the two halves of the Wholist-Analytic dimension (23 Wholist subjects and 27 Analytic subjects, table 26), with a slightly more uneven division of subjects between the two halves of the Verbal-Imagery dimension (21 Verbaliser subjects and 29 Imager subjects, table 26).

Figure 96 plots the CS of subjects who performed the experiments. The vertical axis plots subjects' Wholist-Analytic classification and the horizontal axis plots their Verbal-Imagery classification. As shown in figure 96 most subjects were clustered around the middle section of the Wholist-Analytic dimension, while there is a more even spread along the Verbal-Imagery dimension. Figure 96 also identifies one extreme Analytic subject along the Wholist-Analytic dimension with a classification of over 4.

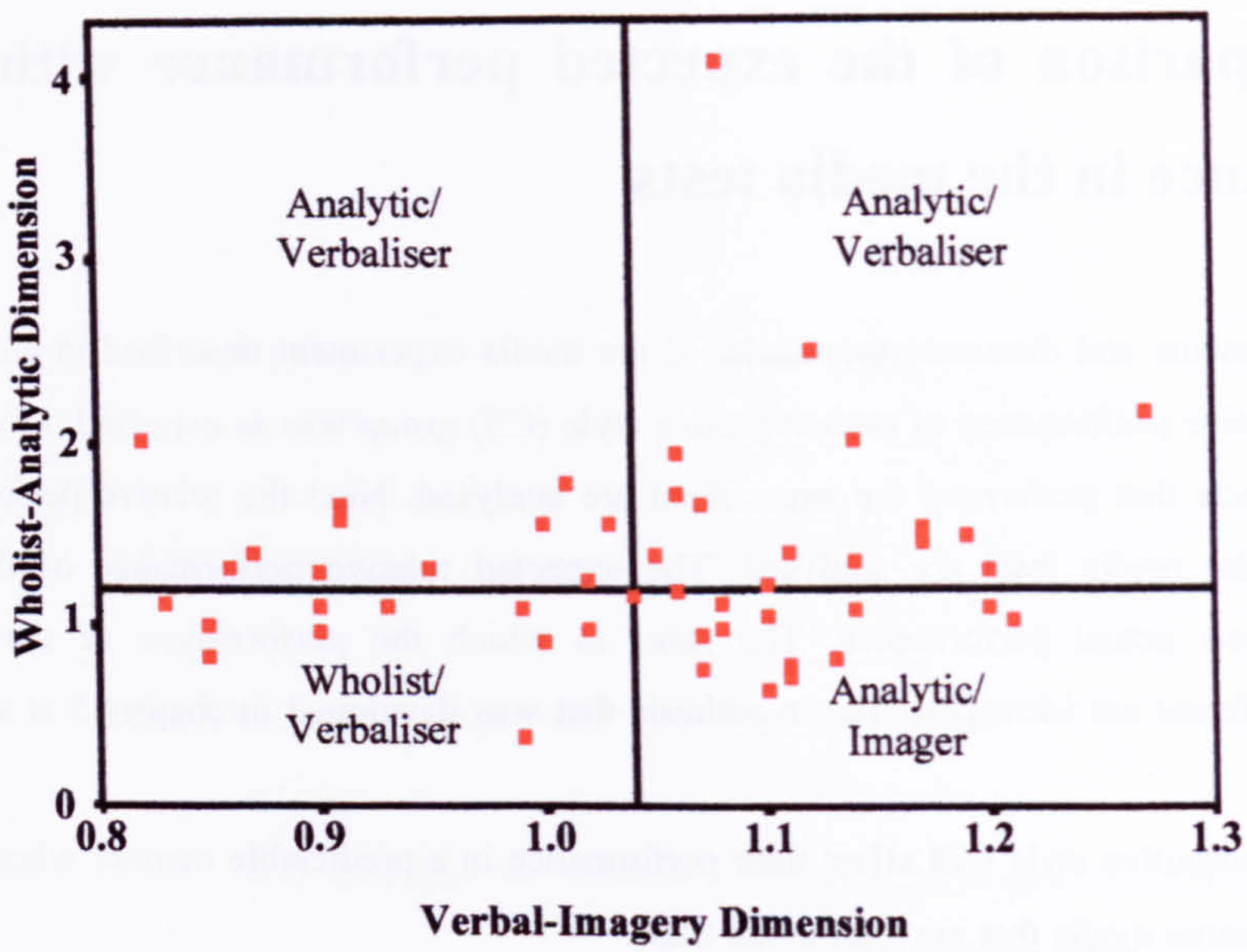


Figure 96: Scatter-graph of subjects cognitive style classification

In order to compare the relative performance of subjects between each task a number of calculations had to be performed on the results. Scores were calculated as the percentage of questions answered correctly and duration figures were calculated as *the average time* taken to answer one question. The duration figure included only the time taken to answer questions and not the time taken to view the information. For each subject scores are divided by duration to produce a PR. As this measure combines both the score and duration it provides an overall measure of performance (chapter 5). The results of subjects are analysed for each CS group considering each dimension separately and by comparing the results of the four CS quadrants formed by combining the two dimensions. The relative performance of the CS groups in each task is compared to the expected performance.

The results of each test are presented by first examining the results of each task individually and then by grouping tasks by the CS that each task was expected to suit. For each task it is noted whether the relative performance of the CS groups were as expected when comparing the mean PRs. The relative performance of the CS groups give an indication of the expected performance of subjects when presented with similar tasks, however, it cannot be concluded that one CS group performed better than another unless the performance of each group was significantly different. To test whether the performance of the CS groups was significantly different one-way and two-way ANOVA calculations were performed. The tasks in which there is a significant or marginally significant interaction between performance and CS are examined to determine whether the relative performance of the CS groups supports the hypothesis.

6.2 Results of the text test

The text test required subjects to perform a number of tasks where information was presented by displaying text (chapter 5). The results of the text test are presented both by examining the results of each task individually and then by grouping tasks by the CS groups in each task. The relative performance of the CS groups in each task are discussed by first comparing the mean results and then by assessing the degree to which the performance of each group was statistically different.

6.2.1 Performance of the text test tasks

The mean results tables in this chapter follow the same format as table 27. The columns show the results of subjects split into all the different combinations of CS. The **ALL** column shows the results for all subjects regardless of CS. The next two columns show the results of subjects divided into their Wholist-Analytic classification regardless of their Verbal-Imagery classification. The **W** column shows the results for all Wholist subjects and the **A** column shows the results for all Analytic subjects. The next two columns show the results of subjects divided into their Verbal-Imagery classification regardless of their Wholist-Analytic classification. The **V** column shows the results of all Verbaliser subjects and the **I** column shows the results for all Imager subjects. The last four columns show the results for the four quadrants formed by combining the two dimensions; Wholist/Verbaliser (**WV**), Wholist/Imager (**WI**), Analytic/Verbaliser (**AV**) and Analytic/Imager (**AI**). The **Questions** column indicates how many questions were asked in each category of task.

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
T_CON	5	16.92 (-6.88)	18.07 (7.71)	15.94 (6.05)	17.08 (8.06)	16.81 (6.02)	18.21 (9.68)	17.96 (6.22)	16.04 (6.57)	15.87 (5.89)
T_OBJ	5	18.07 (-7.47)	19.24 (8.69)	17.07 (6.25)	17.56 (7.29)	18.44 (7.70)	17.93 (8.63)	20.25 (8.94)	17.22 (6.24)	16.96 (6.45)
T_MAT	3	9.14 (-4.80)	9.18 (4.80)	9.11 (4.89)	8.37 (4.25)	9.70 (5.16)	8.89 (4.43)	9.40 (5.23)	7.90 (4.23)	9.94 (5.27)
T_PRO	5	5.59 (-3.86)	6.63 (4.98)	4.71 (2.30)	6.28 (4.47)	5.10 (3.34)	7.41 (5.91)	6.04 (4.29)	5.25 (2.49)	4.34 (2.16)
T_PNC	3	8.69 (-6.15)	10.20 (6.84)	7.40 (5.29)	10.39 (6.22)	7.46 (5.90)	10.58 (7.56)	9.9 (6.52)	10.22 (5.09)	5.47 (4.64)
T_PWC	2	3.61 (-3.47)	4.10 (4.34)	3.20 (2.52)	3.99 (4.34)	3.34 (2.71)	5.32 (5.52)	3.17 (3.07)	2.78 (2.63)	3.48 (2.48)
T_COM	8	7.06 (-2.67)	6.72 (2.55)	7.35 (2.79)	6.96 (2.86)	7.13 (2.58)	6.92 (3.29)	6.56 (1.93)	6.99 (2.57)	7.59 (2.98)

Table 27: Text test mean results

The rows show the results for the different categories of task performed in the experiment. For each task the mean PRs are displayed with the standard deviation in brackets. The prefix **T_** indicates that the tasks were performed as part of the text test. The tasks are identified as the *comparison of objects* task (**T_OBJ**), the *comparison of concepts* task (**T_CON**), the *mathematics* task (**T_MAT**), the *procedural* task (**T_PRO**) and the *comprehension* task (**T_COM**). The *procedural* task is further broken down to show the results for the *procedural* task questions that did not require calculations to be performed (**T_PNC**) and the *procedural* task questions that included calculations (**T_PWC**).

By comparing the mean results of subjects in each CS group it is possible to gain an indication of whether the tasks were performed as expected. The cells highlighted with yellow indicate the tasks that were performed as expected while the cells highlighted with red indicate the tasks that were performed opposite to expectations.

It was expected that Wholists would perform the T_PNC task better than Analytics while Analytics would perform the T_COM, T_MAT and T_PWC tasks better than Wholists (chapter 5).

The text test appeared to suit Wholists more than Analytics as six of the seven categories of task were performed better by Wholists than Analytics. The task that was expected to be performed better by Wholists was performed as expected as in the T_PNC task (Wholists PR=10.20, Analytics PR=7.40, table 27) Wholists achieved higher PRs than Analytics.

Only one of the tasks that were expected to be performed better by Analytics was performed as expected. The T_COM task (Wholists PR=6.72, Analytics PR=7.35, table 27) was performed as expected as Analytics achieved higher PRs than Wholists. In contrast two tasks were performed opposite to expectations. In the T_PWC task (Wholists PR=4.10, Analytics PR=3.20, table 27) and in the T_MAT task (Wholists PR=9.18, Analytics PR=9.11, table 27) Analytics achieved lower PRs than Wholists.

The Wholist-Analytic classification of subjects also appeared to be important in other tasks as the difference between Wholists (PR=18.07) and Analytics (PR=15.94) in the T_CON task was greater than the difference between the Verbalisers (PR=17.08) and Imagers (PR=16.81). Subjects in the two Wholist quadrants (WV PR=17.93 and WI PR=20.25, table 27) also performed better than the two Analytic quadrants (AV PR=17.22 and AI PR=16.96, table 27).

It was expected that Verbalisers would perform the T_CON, T_PRO, T_COM and T_MAT tasks better than Imagers while Imagers would perform the T_OBJ task better than Verbalisers (Chapter 5).

There was an even spread of performance between Verbalisers and Imagers as four of the categories of task were performed better by Verbalisers and three were performed better by Imagers (table 27). Two of the tasks that were expected to be performed better by Verbalisers were performed as expected while two were not. In the T_CON task (Verbalisers PR=17.08, Imagers PR=16.81, table 27) and the T_PRO task (Verbalisers PR=6.28, Imagers PR=5.10, table 27) were performed as expected while the T_COM task (Verbalisers PR=6.96, Imagers PR=7.13, table 27) and the T_MAT task (Verbalisers PR=8.37, Imagers PR=9.70, table 27) were performed opposite to prior expectations.

The task that Imagers were expected to perform best was performed as expected as Imagers (PR=18.44, table 27) performed the T_OBJ task better than Verbalisers (PR=17.56, table 27).

The mean results show a wide variation of performance between the tasks. The average PR for all subjects range from 3.61 in the T_PWC task to 18.07 for the T_OBJ task (table 27).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
T_CON	1.12	0.30	0.02	0.18	0.01	0.92	0.00	0.05
T_OBJ	0.85	0.36	0.02	0.15	0.22	0.64	0.01	0.08
T_MAT	0.03	0.87	0.00	0.05	0.83	0.37	0.02	0.15
T_PRO	3.12	0.08	0.06	0.41	1.09	0.30	0.02	0.18
T_PNC	2.00	0.16	0.04	0.28	2.56	0.12	0.05	0.35
T_PWC	1.25	0.27	0.03	0.19	0.54	0.47	0.01	0.11
T_COM	0.49	0.49	0.01	0.11	0.02	0.88	0.00	0.05

Table 28: Text test tasks one-way ANOVA

The results of the one-way ANOVA shown in table 28 presents the **F** statistic, the level of **significance, Eta Squared** and the **Observed Power** for the comparisons of performance between the CS groups. The calculations assess the performance of Wholists against Analytics (WA) and Verbalisers against Imagers (VI) to determine whether there was a significant interaction between CS and performance. Where a significant interaction is detected the background of the cell is coloured yellow and where a marginally significant effect is detected the background is coloured green.

Table 28 shows that there were no tasks in which there was a significant interaction between CS and performance, however there was one task in which a marginal effect was detected. A marginal interaction was detected between PRs achieved in the T_PRO task and subjects' Wholist-Analytic classification (p=0.08, table 28). This result is supported by the Eta squared figure of 0.06 that indicates that 6% of the variability of performance among the subjects' can be attributable to their CS classification. Similarly the observed power of 0.41 is relatively high compared to the other results which indicate that there is less of a possibility of a type II error. Wholists did perform the task better than Analytics achieving a PR of 6.63 compared to 4.71 (table 27). The T_PRO task contained a mixture of questions that were suitable for Wholists and Analytics and although the task contained more Wholist style questions than Analytic style questions neither group were expected to perform the task significantly better than the other.

Table 28 identifies no tasks in which there were significant or marginally significant interactions between the performance of Verbalisers and Imagers.

The level of significance for the interaction between performance and CS was low for all tasks. No significant interactions were detected and only one marginally significant interaction between performance and CS was detected. No interaction was detected for the tasks grouped together in terms of the CS groups that were expected to perform the task better. The highest F statistic value was 3.12 which was too low to indicate a significant result. The highest Eta squared value indicated only 6% of the variance in subjects' results was due to the CS classification of subjects. The low observed power values indicate there is a possibility of a type II error of rejecting an effect where there is one. Where the marginal effect was detected the observed power was higher but the value of 0.41 may not be high enough to confidently reject the possibility of a type I error of concluding that there was an effect where there is no effect.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
T_OBJ * T_CON	1.45	0.24	0.03	0.22	0.06	0.81	0.00	0.06
T_PNC * T_PWC	2.46	0.12	0.05	0.34	2.36	0.13	0.05	0.33

Table 29: Text test tasks two-way ANOVA

A two-way ANOVA was performed to test whether the relative difference in performance of the CS groups in one task is matched by a corresponding difference in another task. The performance of subjects in the T_OBJ task (that was expected to be performed better by Imagers) was compared against the performance of subjects in the T_CON task (that was expected to be performed better by Verbalisers) and the performance of subjects in the T_PNC task (that was expected to be performed better by Wholists) was compared against the performance of subjects in the T_PWC task (that was expected to be performed better by Analytics). No significant interaction between CS and performance was detected (table 29). The lack of a significant two-way interaction between the performance in two tasks and CS is not surprising when no interaction was found between performance of any of these tasks individually and CS.

In order to explain why no significant differences were detected between the performance of the CS groups the difference between the text test tasks and the CSA test were examined. One difference was the number of questions used in each task. In order to examine the performance of subjects over a wide range of tasks in a short time the number of questions in each task was kept low. This contrasts with the CSA test that uses a relatively large number of questions and has one style of task that is suited to each CS group. Differences in performance between the CS groups may be slight and may only be revealed over a large number of questions.

6.2.2 Results of the text test by style of task

The results of tasks that were expected to be suited to each CS were grouped together in order to determine whether the performance of the different CS groups were as expected. The mean results of all CS groups are shown in table 30.

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
T_W	3	8.69 (6.15)	10.20 (6.84)	7.40 (5.29)	10.39 (6.22)	7.46 (5.90)	10.58 (7.56)	9.90 (6.52)	10.22 (5.09)	5.47 (4.64)
T_A	13	6.55 (2.26)	6.41 (2.28)	6.67 (2.28)	6.36 (2.49)	6.69 (2.12)	6.80 (2.92)	6.11 (1.71)	5.96 (2.08)	7.16 (2.34)
T_V	21	8.14 (2.45)	8.33 (2.80)	7.97 (2.16)	8.14 (2.85)	8.13 (2.17)	8.69 (3.38)	8.06 (2.36)	7.64 (2.32)	8.19 (2.09)
T_I	5	18.07 (7.47)	19.24 (8.69)	17.07 (6.25)	17.56 (7.29)	18.44 (7.70)	17.93 (8.63)	20.25 (8.94)	17.22 (6.24)	16.96 (6.45)

Table 30: Text test tasks mean results by style of task

When all the questions are divided into the style of task (the task style is the CS group that were expected to perform the task best) the relative performance of all CS groups was as expected (as indicated by the yellow backgrounds in table 30). Wholists performed the Wholist tasks (Wholists PR=10.20, Analytics PR=7.40, table 30) better than Analytics and Analytics performed the Analytic tasks (Wholists PR=6.41, Analytics PR=6.67, table 30) better than Wholists. Similarly Verbalisers performed the Verbaliser tasks (Verbalisers PR=8.14, Imagers PR=8.13, table 30) better than Imagers and Imagers performed the Imager tasks (Verbalisers PR=18.44, Imagers PR=17.56, table 30) better than Verbalisers.

Although the relative performance of the CS groups were as expected (table 30) the between-subjects effects of the one-way ANOVA calculations indicate that there were no significant interactions between performance and CS ($p>0.10$, table 31).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
T_W	2.00	0.16	0.04	0.28	2.56	0.12	0.05	0.35
T_A	0.03	0.87	0.00	0.05	0.16	0.70	0.00	0.07
T_V	0.41	0.53	0.01	0.10	0.00	0.96	0.00	0.05
T_I	0.85	0.36	0.02	0.15	0.22	0.64	0.01	0.08

Table 31: Text test tasks by style of task one-way ANOVA

By grouping tasks together by style it is possible to compare performance over a larger number of questions, however no significant differences in performance between the CS groups were revealed. This may be because of the complexity of the tasks being performed. The CSA test uses a large number of simple tasks while the text test used a range of tasks with differing levels of complexity. Combining tasks that contain different levels of complexity did not result in the same relative performance as observed in the CSA test.

A two-way analysis of variance calculation was performed to compare the performance of the CS groups between the different styles of question. The performance of subjects in the Wholist style tasks were compared with the performance of subjects in the Analytic style tasks and the performance of subjects in the Verbaliser style tasks were compared against the performance of subjects in the Imager style tasks. No significant interaction between performance and CS in one style of task was matched by a corresponding interaction in the other style of task (table 32).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
T_W * T_A	1.45	0.24	0.03	0.22	1.66	0.20	0.04	0.24
T_V * T_I	0.88	0.35	0.02	0.15	0.14	0.71	0.00	0.07

Table 32: Text test tasks by style of task two-way ANOVA

6.2.3 Summary of the results of the text test

The results of the text task did not produce any evidence to support or contradict the hypothesis that performance of the CS groups can be predicted when using the same media as the CSA test. The T_CON and T_OBJ tasks were similar to the Verbaliser and Imager style tasks used in the CSA test and used the same media, but no significant difference was detected in the performance of either task. No significant differences were found between the performance of the CS groups except in the T_PRO task that was performed better by Wholists with a marginally significant interaction between CS and performance. As this task contained a mixture of questions that were suited to both Wholists and Analytics this result is classified as neutral in the summary table (table 33).

As expected
• None
Neutral
• **Procedural** task - performed best by **Wholists**
Opposite to expected
• None

Table 33: Text test summary of results

Differences between the text test and the CSA test appear to be due to the number of questions used in the test and the complexity of the tasks performed and no difference can be attributed to the media used.

6.3 Results of the image test

The image test required subjects to perform a number of tasks where information was presented using images with the minimum of text (chapter 5). The results of the image test are presented in the same manner as the text test.

6.3.1 Performance of the image test tasks

The results of all the CS groups in each of the tasks performed in the image test are shown in table 34. The information is displayed in the same manner as table 27 using the **I_** prefix referring to the image test. The tasks are identified as the *comparison of physical attributes of objects* task (**I_PhOB**), the *comparison of types of objects* task (**I_TOB**), the *comparison of objects* task (**I_OBJ**), the *configuration* task (**I_CFG**) and the *mathematics* task (**I_MAT**).

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
I_PhOB	12	10.15 (2.47)	10.83 (2.45)	9.57 (2.38)	10.26 (2.63)	10.07 (2.39)	11.28 (2.76)	10.49 (2.23)	9.33 (2.22)	9.73 (2.54)
I_TOB	4	12.46 (3.63)	12.16 (3.21)	12.71 (4.01)	13.86 (3.66)	11.44 (3.32)	13.03 (2.29)	11.49 (3.72)	14.61 (4.55)	11.40 (3.09)
I_OBJ	4	12.10 (4.24)	11.37 (4.22)	12.73 (4.23)	12.25 (3.04)	12.00 (4.98)	11.71 (3.11)	11.11 (5.02)	12.73 (3.04)	12.73 (4.99)
I_CFG	10	6.21 (2.24)	5.97 (1.90)	6.42 (2.51)	6.88 (2.51)	5.73 (1.93)	5.98 (1.35)	5.97 (2.30)	7.70 (3.07)	5.54 (1.62)
I_MAT	3	10.21 (3.47)	9.70 (3.72)	10.65 (3.26)	10.42 (4.04)	10.07 (3.07)	10.50 (4.73)	9.09 (2.75)	10.34 (3.53)	10.86 (3.17)

Table 34: Image test mean results

It was expected that Wholists would perform the I_TOB task better than Analytics while Analytics would perform the I_PhOB, I_OBJ, I_CFG and I_MAT tasks better than Wholists (chapter 5).

In contrast to the text test, the image test appeared to suit Analytics more than Wholists as four of the five categories of task were performed better by Analytics than Wholists. The task that was expected to be performed better by Wholists was not performed as expected as in the I_TOB task (Wholists PR=12.16, Analytics PR=12.71, table 34) Wholists achieved a lower PR than Analytics.

Three of the four tasks that Analytics were expected to perform better than Wholists were performed as expected while one task was performed opposite to the prior expectation. In the I_OBJ task (Wholists PR=11.37, Analytics PR=12.73, table 34), the I_CFG task (Wholists PR=5.97, Analytics PR=6.42, table 34) and the I_MAT task (Wholists PR=9.70, Analytics PR=10.62, table 34) Analytics achieved higher PRs than Wholists, while the I_PhOB task (Wholists PR=10.83, Analytics PR=9.57, table 34) was performed opposite to prior expectations as Wholists achieved a higher PR than Analytics.

It was expected that Verbalisers would perform the I_MAT task better than Imagers while Imagers would perform the I_PhOB, I_TOB, I_OBJ and I_CFG tasks better than Verbalisers (chapter 5).

The image test appeared to suit Verbalisers more than Imagers as all five categories of task were performed better by Verbalisers than Imagers. The task that Verbalisers were expected to perform better than Imagers was performed as expected as in the I_MAT task (Verbalisers PR=10.42, Imagers PR=10.07, table 34) Verbalisers achieved a higher PR than Imagers. In contrast all four of the tasks that were expected to be performed best by Imagers were performed opposite to prior expectation. In the I_PhOB task (Verbalisers PR=10.26, Imagers PR=10.07, table 34), the I_TOB task (Verbalisers PR=13.86, Imagers PR=11.44, table 34) the I_OBJ task (Verbalisers PR=12.25, Imagers PR=12.00, table 34) and the I_CFG task (Verbalisers PR=6.88, Imagers PR=5.73, table 34) Imagers achieved lower PRs than Verbalisers.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
I_PhOB	3.72	0.06	0.08	0.47	0.08	0.78	0.00	0.06
I_TOB	0.56	0.46	0.01	0.11	5.56	0.02	0.11	0.64
I_OBJ	1.14	0.29	0.02	0.18	0.06	0.81	0.00	0.06
I_CFG	1.10	0.30	0.02	0.18	3.07	0.09	0.06	0.40
I_MAT	0.64	0.43	0.01	0.12	0.20	0.66	0.00	0.07

Table 35: Image test tasks one-way ANOVA

The results of the one-way ANOVA calculations shown in table 35 identified three tasks in which there was a significant or marginally significant interaction between performance and CS.

A marginally significant interaction was detected between performance in the Wholist-Analytic classification of subjects in the I_PhOB task (p=0.06, table 35). This result was supported by the relatively high Eta squared value of 0.08 and the relatively high observed power value of 0.47. Wholists performed better than Analytics (Wholists PR=10.83, Analytics PR=9.57, table 34) which was opposite to the expected result. The reason why this task was not performed as expected may be due to the type of activities subjects had to perform. The I_PhOB task contained three types of question:

a) Determine whether one object contained in the other
b) Assess the distance between objects
c) Select the largest object

It was expected that Analytics would perform better than Wholists because the questions asked subjects to distinguish between the components that make up the objects or the whole situation. Type a) questions were similar to the Analytic style questions in the CSA test except that the questions used photographic images rather than simple graphical images. Type b) questions were similar to configuration type questions, which were also expected to suit Analytics, as subjects had to assess the position of a number of objects in relation to each other. However, the CS that type c) questions were expected to suit was more ambiguous as the objects could be regarded as separate wholes and the relationship between them was not the important factor other than the relative size.

There was a significant interaction between performance and the Verbal-Imagery classification of subjects in one task and a marginally significant interaction in another task. A significant interaction was detected between the performance of the I_TOB task ($p=0.02$, table 35) depending on subjects' Verbal-Imagery classification. The result is supported by the relatively high F statistic of 5.56, the relatively high Eta squared value of 0.11 and the observed power of 0.64. The performance of this task was opposite to what was expected as Verbalisers performed better than Imagers (Verbalisers PR=13.86, Imagers PR=11.44, table 34). A marginally significant interaction was detected between the performance of the I_CFG task ($p=0.09$, table 35) depending on subjects' Verbal-Imagery classification. This result is supported by the relatively high Eta squared value of 0.06 and the relatively high observed power value of 0.40. Verbalisers unexpectedly performed better than Imagers (Verbalisers PR=6.88, Imagers PR=5.73, table 34).

In both the tasks in which there was a significant or marginally significant interaction between performance and the Verbal-Imagery classification of subjects the Verbalisers unexpectedly performed better than Imagers. Both tasks were expected to suit Imagers because both presented information pictorially, therefore the activities involved in both tasks were examined in order to identify the features that made them suitable for Verbalisers. The I_TOB task presented three objects and subjects were asked to identify the odd one out. The activities involved recognising the objects and then identifying the conceptual associations between them. The I_CFG task presented a map and the questions asked how objects were related on the map. Although the questions showed objects text was used in the question to indicate the conceptual link between the objects that were being considered (e.g. which objects were nearest each other, how many left turns between the objects etc.). The common link between the two types of task was that the conceptual associations between the objects depicted in the images were being examined. Verbalisers are shown to perform better than Imagers when considering the conceptual associations between the objects which may be due to the way they assign labels to related objects while Imagers associate objects by their appearance, which could speed up the recall of related objects.

The Tukey calculations identified that performance of two of the CS quadrants were significantly different in the I_CFG. Table 36 shows the results of the Tukey calculations that compare the performance of each CS quadrant against each of the others. A significance figure of less than 0.05 (highlighted with the yellow background) indicates where the performance of two tasks was significantly different while a significance figure of between 0.05 ands 0.10 indicates there was a marginally significant difference of performance. There was a marginally significant difference between the performance of the Analytic/Verbaliser and the Analytic Imager quadrants ($p=0.06$, table 36). Analytic/Verbalisers performed the task best while Analytic/Imagers performed the task worst (table 36).

		I_CFG
Wholist/Verbaliser	Wholist/Imager	1.00
	Analytic/Verbaliser	0.27
	Analytic/Imager	0.96
Wholist/Imager	Wholist/Verbaliser	1.00
	Analytic/Verbaliser	0.22
	Analytic/Imager	0.95
Analytic/Verbaliser	Wholist/Verbaliser	0.27
	Wholist/Imager	0.22
	Analytic/Imager	0.06
Analytic/Imager	Wholist/Verbaliser	0.96
	Wholist/Imager	0.95
	Analytic/Verbaliser	0.06

Table 36: Image configuration task Tukey results

The relative performance of the CS quadrants reinforces the marginally significant interaction observed between performance and the Verbal-Imagery classification of subjects and also demonstrates that performance is influenced by both dimensions. The configuration task was expected to suit Analytics and while no significant difference was detected between the performance of Analytics and Wholists there was a marginally significant difference between Analytics depending on whether they were Verbalisers or Imagers. It may not be possible to make reliable predictions of performance for individuals depending on their Wholist-Analytic classification without reference to their Verbal-Imagery classification.

6.3.2 Results of the image test by style of task

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
I_W	4	12.46 (3.63)	12.16 (3.21)	12.71 (4.01)	13.86 (3.66)	11.44 (3.32)	13.03 (2.29)	11.49 (3.72)	14.61 (4.55)	11.40 (3.09)
I_A	29	8.61 (1.89)	8.68 (1.86)	8.55 (1.96)	8.98 (1.92)	8.34 (1.87)	9.05 (1.75)	8.39 (1.96)	8.92 (2.15)	8.31 (1.85)
I_V	3	10.21 (3.47)	9.70 (3.72)	10.65 (3.26)	10.42 (4.04)	10.07 (3.07)	10.50 (4.73)	9.09 (2.75)	10.34 (3.53)	10.86 (3.17)
I_I	30	8.89 (1.95)	8.95 (1.87)	8.84 (2.05)	9.42 (1.96)	8.51 (1.89)	9.37 (1.55)	8.62 (2.09)	9.46 (2.35)	8.41 (1.77)

Table 37: Image test tasks mean results by style of question

The performance of subjects in tasks that were divided into style of task was as expected for Verbalisers (as indicated by the yellow backgrounds in table 37) but not for Wholists, Analytics or Imagers (as indicated by the red backgrounds in table 37). Verbalisers performed the Verbaliser tasks (Verbalisers PR=10.42, Imagers PR=10.07, table 37) better than Imagers while Wholists performed the Wholist tasks (Wholists PR=12.16, Analytics PR=12.71, table 37) worse than Analytics, Analytics performed the Analytic tasks (Wholists PR=8.68, Analytics PR=8.55, table 37) worse than Wholists and Imagers performed the Imager tasks (Verbalisers PR=9.42, Imagers PR=8.51, table 37) worse than Verbalisers.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
I_W	0.56	0.46	0.01	0.11	5.56	0.02	0.11	0.64
I_A	0.04	0.84	0.00	0.05	1.31	0.26	0.03	0.20
I_V	0.64	0.43	0.01	0.12	0.20	0.66	0.00	0.07
I_I	0.01	0.92	0.00	0.05	2.54	0.12	0.05	0.35

Table 38: Image test tasks one-way ANOVA

When the results of tasks grouped by the CS of the tasks are analysed using the one-way ANOVA calculation one interaction between performance and the CS of subjects is detected (table 38). In the Wholists tasks an interaction between PR and the Verbal-Imagery classification of subjects (p=0.02) was detected. This result was supported by the relatively high F statistic of 5.56, the relatively high Eta squared value of 0.11 and the observed power of 0.64. The only Wholist style task was the I_TOB task that was also expected to suit Verbalisers as discussed above. No interactions between performance and CS were detected in the tasks that were expected to suit each CS group.

A two-way ANOVA calculation was performed to compare the performance of subjects between the different styles of task. A significant interaction between performance and CS was detected when comparing the performance of Wholist and Analytic tasks which depended on subjects' Verbal-Imagery classification (p=0.03). This result was supported by the relatively high F statistic of 4.92, the relatively high Eta squared value of 0.10 and the observed power of 0.58. There was only one task that was suitable for Wholists which was a relatively simple task (picking the odd one out from three objects), while there were more Analytic style tasks which were relatively complex.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
I_W * I_A	0.22	0.64	0.01	0.08	4.92	0.03	0.10	0.58
I_V * I_I	0.32	0.58	0.01	0.09	1.03	0.32	0.02	0.17

Table 39: Image test tasks by style of tasks two-way ANOVA

6.3.3 Summary of the results of the image test

The results of the image test do not support the hypothesis that the relative performance of the CS groups can be predicted when using the same media as the CSA test. There were three tasks in which there was a significant or marginally significant interaction between performance and CS and in each the performance was opposite to expected (as indicated in table 40). On closer examination of the tasks there were aspects contained in the task that were found to be suitable for the CS group that performed best. The I_PhOB task contained questions that were similar to the Analytic style questions in the CSA test and used the same media (although using more complex images) but Wholists unexpectedly performed best. The tasks were more complex than the tasks performed in the CSA test and contained aspects suitable to more than one CS group, and it was not possible to predict which aspect would have more influence on the performance of subjects.

More significant differences were detected between Verbalisers and Imagers than between Wholists and Analytics. No significant differences in performance were detected between the Wholist tasks by Wholists or Analytics but significant differences were detected between Verbalisers and Imagers in the Wholist and Analytic tasks.

The classification of individuals CS along both dimensions was found to be important and general recommendations for subjects of one CS may depend on their classification along the other dimension.

Neutral

- **Configuration** - performed best by **Analytic/Verbalisers**

As expected

- None

Opposite to expected

- **Comparison of Physical attributes of objects** - performed best by **Analytics**
- **Comparison of types of objects** - performed best by **Verbalisers**
- **Configuration** - performed best by **Verbalisers**

Table 40: Image test summary of results

6.4 Results of the text/image test

The text/image test examined the performance of subjects in a series of tasks when information is presented visually using a combination of text and images (chapter 5). The results of the text/image test are presented in the same manner as the text and image tests.

6.4.1 Performance of the text/image test tasks

The results of all the CS groups in each of the tasks performed in the text/image test are shown in table 41. The information is displayed in the same manner as table 27 using the **TI_** prefix referring to the text/image test. The tasks are identified as the *comparison of objects* task (**TI_OBJ**), the *procedural* task (**TI_PRO**), the *configuration* task (**TI_CFG**) and the *mathematics* task (**TI_MAT**). The *procedural* task is further divided into the *procedural* task questions that did not require calculations to be performed (**TI_PNC**) and the *procedural* task questions that included calculations (**TI_PWC**).

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
TI_OBJ	10	14.54 (4.06)	15.05 (4.30)	14.10 (3.86)	15.26 (4.38)	14.02 (3.80)	14.73 (4.89)	15.30 (3.98)	15.74 (4.05)	12.98 (3.41)
TI_PRO	5	7.02 (3.08)	6.56 (2.66)	7.42 (3.39)	7.20 (3.35)	6.90 (2.91)	6.07 (2.00)	6.93 (3.10)	8.22 (4.06)	6.87 (2.85)
TI_PNC	4	9.14 (3.67)	8.46 (3.68)	9.72 (3.62)	8.68 (3.64)	9.48 (3.71)	7.70 (2.75)	9.05 (4.28)	9.56 (4.23)	9.83 (3.28)
TI_PWC	1	3.44 (6.00)	3.15 (5.37)	3.69 (6.57)	4.70 (7.18)	2.52 (4.90)	2.79 (4.98)	3.42 (5.84)	6.44 (8.60)	1.80 (4.03)
TI_CFG	5	6.11 (2.91)	6.33 (3.22)	5.92 (2.66)	6.45 (2.80)	5.86 (3.01)	6.75 (3.02)	6.01 (3.44)	6.18 (2.70)	5.75 (2.71)
TI_MAT	3	12.30 (5.44)	11.81 (5.75)	12.72 (5.24)	12.21 (4.20)	12.37 (6.26)	11.30 (4.20)	12.20 (6.85)	13.04 (4.22)	12.51 (5.96)

Table 41: Text/image test mean results

It was expected that Wholists would perform the TI_PNC task better than Analytics while Analytics would perform the TI_PWC and TI_MAT tasks better than Wholists (chapter 5).

Like the image test, the text/image test appeared to suit Analytics more than Wholists as four of the six categories of task were performed better by Analytics than Wholists. The task that was expected to be performed better by Wholists was not performed as expected as in the TI_PNC task (Wholists PR=8.46, Analytics PR=9.72, table 41) Wholists achieved a lower PR than Analytics.

One of the tasks that Analytics were expected to perform better than Wholists was performed as expected while the other was performed opposite to the prior expectation. Analytics achieved a higher PR than Wholists in the TI_PWC task (Wholist PR=3.15, Analytics PR=3.69, table 41) but achieved a lower PR in the TI_MAT task than Wholists (Wholist PR=11.81, Analytics PR=12.72, table 41).

It was expected that Verbalisers would perform the TI_PRO and TI_MAT tasks better than Imagers while Imagers would perform the TI_OBJ and TI_CFG tasks better than Verbalisers.

As in the image test the text/image test appeared to suit Verbalisers more than Imagers as four of the six categories of task were performed better by Verbalisers than Imagers. One of the tasks that Verbalisers were expected to perform better than Imagers was performed as expected while the other was performed opposite to the prior expectation. Verbalisers achieved a higher PR than Imagers in the TI_PRO task (Verbalisers PR=7.20, Imagers PR=6.90, table 41) but achieved a lower PR in the TI_MAT task than Imagers (Verbalisers PR=12.21, Imagers PR=12.37, table 41).

Both of the tasks that Imagers were expected to perform better than Verbalisers were performed opposite to the prior expectation. Imagers achieved a lower PR than Verbalisers in the TI_OBJ task (Verbalisers PR=15.26, Imagers PR=14.02, table 41) and the TI_CFG task (Verbalisers PR=6.45, Imagers PR=5.86, table 41).

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
TI_OBJ	0.32	0.58	0.01	0.09	0.91	0.35	0.02	0.15
TI_PRO	1.39	0.24	0.03	0.21	0.08	0.78	0.00	0.06
TI_PNC	1.55	0.22	0.03	0.23	0.58	0.45	0.01	0.12
TI_PWC	0.36	0.55	0.01	0.09	1.39	0.25	0.03	0.21
TI_CFG	0.23	0.63	0.01	0.08	0.47	0.50	0.01	0.10
TI_MAT	0.41	0.53	0.01	0.10	0.01	0.91	0.00	0.05

Table 42: Text/image test tasks one-way ANOVA

The results of the one-way ANOVA calculations as shown in table 42 did not identify any significant or marginally significant interaction between performance and CS for any of the tasks in the text/image test. The level of significance for the interaction between performance and CS was low for all the tasks. The highest F statistic value was 1.55, the highest Eta squared value indicated only 3% of the variance in subjects' results was due to the CS classification of subjects, and the highest observed power value was low at 0.23.

The reason why no link was found between performance and CS may be for the same reasons identified in the text and the image tests, including the low number of questions asked in each task and the complexity of tasks that may contain aspects that suit different CS groups.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
TI_PRO * TI_CFG	0.24	0.63	0.01	0.08	0.42	0.52	0.01	0.10
TI_PNC * TI_PWC	1.44	0.24	0.03	0.22	0.38	0.54	0.01	0.09

Table 43: Text/image test tasks two-way ANOVA

A two-way ANOVA was performed to compare the performance of subjects in the TI_PRO task, that was expected to be performed better by Verbalisers with the performance of subjects in the TI_CFG task, that was expected to be performed better by Imagers. Also the performance of subjects in the TI_PNC task (that was expected to be performed better by Wholists) was compared with the performance of the TI_PWC task (that was expected to be performed better by Analytics). No significant effect was detected for any CS group between these tasks (table 43).

6.4.2 Results of the text/image test by style of task

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
TI_W	4	9.14 (3.67)	8.46 (3.68)	9.72 (3.62)	8.68 (3.64)	9.48 (3.71)	7.70 (2.75)	9.05 (4.28)	9.56 (4.23)	9.83 (3.28)
TI_A	9	6.98 (2.20)	7.07 (2.47)	6.91 (1.98)	7.40 (1.92)	6.68 (2.37)	7.23 (1.84)	6.94 (2.94)	7.55 (2.06)	6.47 (1.86)
TI_V	8	8.61 (2.50)	8.16 (2.38)	8.99 (2.58)	8.70 (1.89)	8.55 (2.89)	7.91 (1.74)	8.35 (2.83)	9.41 (1.81)	8.71 (3.03)
TI_I	15	10.85 (3.13)	11.31 (3.56)	10.47 (2.72)	11.56 (3.37)	10.35 (2.90)	11.37 (3.70)	11.27 (3.60)	11.73 (3.20)	9.60 (2.00)

Table 44: Text/image test tasks mean results by style of question

As in the image task the performance of subjects in tasks that were divided into style of task was as expected for Verbalisers (as indicated by the yellow backgrounds in table 44) but not for Wholists, Analytics or Imagers (as indicated by the red backgrounds in table 41). Verbalisers performed the Verbaliser tasks (Verbalisers PR=8.70, Imagers PR=8.55, table 41) better than Imagers while Wholists performed the Wholist tasks (Wholists PR=8.46, Analytics PR=9.72, table 41) worse than Analytics, Analytics performed the Analytic tasks (Wholists PR=7.07, Analytics PR=6.91, table 41) worse than Wholists and Imagers performed the Imager tasks (Verbalisers PR=11.56, Imagers PR=10.35, table 41) worse than Verbalisers.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
TI_W	1.55	0.22	0.03	0.23	0.58	0.45	0.01	0.12
TI_A	0.02	0.90	0.00	0.05	1.13	0.29	0.02	0.18
TI_V	1.64	0.21	0.03	0.24	0.03	0.86	0.00	0.05
TI_I	0.54	0.47	0.01	0.11	1.57	0.22	0.03	0.23

Table 45: Text/image test tasks by style of task one-way ANOVA

No significant interactions were detected when comparing performance between the tasks when looking at the CS dimensions in isolation (p>10 for all CS groups, table 45).

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
TI_W * TI_A	0.93	0.34	0.02	0.16	0.01	0.92	0.00	0.05
TI_V * TI_I	0.05	0.83	0.00	0.06	0.95	0.34	0.02	0.16

Table 46: Text/image test tasks by style of task two-way ANOVA

The performance of subjects in the Wholist style questions were compared with the performance of subjects in the Analytic style questions and the performance of subjects in the Verbaliser style questions were compared against the performance of subjects in the Imager style questions (table 46). No significant interaction between performance and CS was detected for any of the different styles of task.

6.4.3 Summary of the results of the text/image test

The results of the text/image task do not support the hypothesis that the relative performance of the CS groups would be as expected when using the same media as the CSA test or when processing information in the same parts of the brain as used when performing the CSA test. No significant differences were found between the performance of the CS groups in any of the tasks as summarised in table 47.

As expected
• None
Neutral
• None
Opposite to expected
• None

Table 47: Text/image test summary of results

6.5 Results of the audio test

The audio test examined the performance of subjects in a series of tasks when information is presented without visual cues, using a combination of speech, musical instruments and sound effects (chapter 5). The results of the audio test are presented in the same manner as the other media tests.

6.5.1 Performance of the audio test tasks

The results of all the CS groups in each of the tasks performed in the audio test are shown in table 48. The information is displayed in the same manner as table 27, using the A_ prefix referring to the audio test. The tasks are identified as the *comparison of concepts* task (**A_CON**), the *comparison of objects* task (**A_OBJ**), the *procedural* task (**A_PRO**), the *mathematics* task (**A_MAT**), the *identification of one musical instrument* task (**A_1IN**), the *identification of two musical instruments* task (**A_2IN**), and the *identification of sound effects* task (**A_SFX**). As in the text test the *procedural* task is further divided into the *procedural* task questions that did not require calculations to be performed (**A_PNC**) and the *procedural* tasks questions that included calculations (**A_PWC**).

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
A_CON	4	12.16 (2.31)	12.03 (2.55)	12.28 (2.12)	**12.50 (1.96)**	**11.92 (2.53)**	12.40 (2.42)	11.74 (2.70)	12.60 (1.55)	12.06 (2.47)
A_OBJ	16	14.74 (2.65)	14.93 (2.62)	14.57 (2.72)	**14.14 (3.19)**	**15.17 (2.14)**	14.75 (3.31)	15.08 (2.06)	13.59 (3.13)	15.25 (2.26)
A_PRO	10	9.15 (2.39)	8.50 (2.23)	9.71 (2.42)	**10.07 (2.09)**	**8.49 (2.41)**	9.56 (1.79)	7.68 (2.25)	10.54 (2.31)	9.15 (2.41)
A_PNC	8	10.01 (2.52)	**9.42 (2.48)**	**10.51 (2.48)**	10.44 (2.51)	9.70 (2.52)	10.26 (2.48)	8.77 (2.37)	10.60 (2.65)	10.45 (2.45)
A_PWC	2	7.65 (4.95)	**6.77 (4.81)**	**8.40 (5.04)**	10.18 (5.64)	5.82 (3.46)	8.55 (5.99)	5.40 (3.29)	11.65 (5.13)	6.16 (3.66)
A_MAT	3	10.18 (2.77)	**10.39 (2.68)**	**10.01 (2.88)**	**10.40 (2.82)**	**10.03 (2.77)**	10.17 (3.28)	10.55 (2.24)	10.60 (2.49)	9.60 (3.14)
A_1IN	14	9.95 (3.58)	9.86 (3.85)	10.03 (3.40)	**9.48 (3.92)**	**10.29 (3.34)**	8.58 (4.12)	10.84 (3.48)	10.30 (3.74)	9.84 (3.27)
A_2IN	5	6.36 (3.28)	5.82 (3.23)	6.81 (3.31)	**5.33 (2.91)**	**7.10 (3.38)**	5.05 (3.84)	6.42 (2.69)	5.58 (1.87)	7.66 (3.84)
A_SFX	10	11.68 (2.77)	12.01 (3.51)	11.41 (1.98)	**11.62 (3.05)**	**11.72 (2.61)**	12.47 (3.78)	11.65 (3.39)	10.85 (2.09)	11.79 (1.87)

Table 48: Audio tasks mean results

A
W

It was expected that Wholists would perform A_PNC task better than Analytics while Analytics would perform the A_MAT and A_PWC tasks better than Wholists (chapter 5).

The audio test did not suit either Wholists or Analytics more than each other as there was an even spread of tasks in which Wholists and Analytics performed best. The task that was expected to be performed better by Wholists was not performed as expected as in the A_PNC task Wholists (PR=9.42, table 48) achieved a lower PR than Analytics (PR=10.51, table 48).

One of the tasks that Analytics were expected to perform better than Wholists was performed as expected while the other was performed in an opposite manner to the prior expectation. Analytics achieved a higher PR than Wholists in the A_PWC task (Wholist PR=6.77, Analytics PR=8.40, table 48) but achieved a lower PR in the A_MAT task (Wholist PR=10.39, Analytics PR=10.01, table 48).

V I

It was expected that Verbalisers would perform the A_CON, A_PRO and A_MAT tasks better than Imagers while Imagers would perform the A_OBJ, A_1IN, A_2IN and the A_SFX tasks better than Verbalisers.

The audio test did not suit Verbalisers more than Imagers as there was an even spread of tasks in which Verbalisers and Imagers performed best. All of the tasks that Verbalisers were expected to perform better than Imagers were performed as expected. In the A_CON task (Verbalisers PR=12.50, Imagers PR=11.92, table 48), the A_PRO task (Verbalisers PR=10.07, Imagers PR=8.49, table 48) and the A_MAT task (Verbalisers PR=10.40, Imagers PR=10.03, table 48) Verbalisers achieved higher PRs than Imagers.

All of the tasks that Imagers were expected to perform better than Verbalisers were performed as expected. In the A_OBJ task (Verbalisers PR=14.14, Imagers PR=15.17, table 48), the A_1IN task (Verbalisers PR=9.48, Imagers PR=10.29, table 48), the A_2IN task (Verbalisers PR=5.33, Imagers PR=7.10, table 48) and the A_SFX task (Verbalisers PR=11.62, Imagers PR=11.72, table 48) Imagers achieved higher PRs than Verbalisers.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
A_CON	0.15	0.70	0.00	0.07	0.77	0.38	0.02	0.14
A_OBJ	0.42	0.52	0.01	0.10	1.70	0.20	0.04	0.25
A_PRO	3.64	0.06	0.07	0.46	6.51	0.01	0.12	0.71
A_PNC	2.02	0.16	0.04	0.29	1.32	0.26	0.03	0.20
A_PWC	2.26	0.14	0.05	0.31	11.38	0.00	0.20	0.91
A_MAT	0.10	0.75	0.00	0.06	0.15	0.70	0.00	0.07
A_1IN	0.12	0.73	0.00	0.06	0.75	0.39	0.02	0.14
A_2IN	0.91	0.34	0.02	0.16	3.49	0.07	0.07	0.45
A_SFX	0.84	0.36	0.02	0.15	0.01	0.95	0.00	0.05

Table 49: Audio test tasks one-way ANOVA

A W

The results of the one-way ANOVA calculations shown in table 49 identified a number of tasks in which there was a significant or marginally significant interaction between performance and CS. Only one task indicated subjects' Wholist-Analytic classification affected their performance. There was a marginally significant interaction detected between the PRs achieved and the subjects Wholist-Analytic classification for the A_PRO task (p=0.08, table 49). This result is supported by the Eta squared figure of 0.06 and the relatively high observed power figure of 0.41. Analytics performed this task better than Wholists (table 48) however as the A_PRO task included a mix of questions neither Wholists or Analytics were expected to perform better than each other.

None of the other tasks indicated that there was a significant interaction between performance and the Wholist-Analytic classification of subjects. There were only three tasks that were expected to suit Wholists or Analytics and these were the relatively more complex tasks (including the A_PNC task, the A_PWC task and the A_MAT task).

There were more tasks that were designed to suit Verbalisers or Imagers and more interactions were detected between performance and the Verbal-Imagery style of subjects. A significant interaction between performance and the Verbal-Imagery classification of subjects was detected in the A_PRO task (p=0.01, table 49) which was intensified when removing the questions that did not require calculations to be performed (A_PWC p=0.00, table 49). This result was supported by the relatively high values of the F statistic (11.38), Eta squared (0.20) and the observed power (0.69). Verbalisers performed the A_PRO task better than Imagers (table 48) which was as expected because the task presented information using words.

A marginally significant interaction between performance and the Verbal-Imagery classification of subjects was also detected in the A_2IN task (p=0.07, table 49). Imagers performed the A_PRO task better than Verbalisers (table 48) which was as expected because the information that was presented in the task did not use words.

The performance of two CS quadrants were found to be significantly different in the A_PRO and the performance of one CS quadrant was found to be significantly different from two other CS quadrants in the A_PWC task.

		A_PRO	A_PWC
Wholist/Verbaliser	Wholist/Imager	0.20	0.34
	Analytic/Verbaliser	0.75	0.40
	Analytic/Imager	0.97	0.55
Wholist/Imager	Wholist/Verbaliser	0.20	0.34
	Analytic/Verbaliser	0.02	0.01
	Analytic/Imager	0.30	0.97
Analytic/Verbaliser	Wholist/Verbaliser	0.75	0.40
	Wholist/Imager	0.02	0.01
	Analytic/Imager	0.39	0.01
Analytic/Imager	Wholist/Verbaliser	0.97	0.55
	Wholist/Imager	0.30	0.97
	Analytic/Verbaliser	0.39	0.01

Table 50: Audio procedural tasks Tukey results

Table 50 shows the results of the Tukey calculations. In the A_PRO task the performance of Wholist/Imagers was significantly different from the Analytic/Imagers (p=0.02, table 50). In the A_PNC task Analytic/Verbalisers were shown to have performed in a significantly different manner from the Wholist/Imagers (p=0.01, table 50) and the Analytic Imagers (p=0.00, table 50). Analytic/Verbalisers performed the task best while Analytic/Imagers and Wholist/Imagers performed the task second worst and worst respectively (table 48).

The results of the Tukey calculations reflect the significant interaction observed between Verbalisers and Imagers and also shows the influence that both dimensions have on the performance of complex tasks. Both of the *procedural* tasks were expected to be suitable for Verbalisers and Verbalisers performed best in both tasks (table 48) and performance was significantly different from Imagers (table 49). Analytics were expected to perform better at the A_PWC task and performed better than Wholists in both types of *procedural* questions (table 48) and there was a marginally significant difference in performance with Wholists for the A_PRO task overall (table 49). When combining both dimensions the subjects in the Analytic/Verbaliser quadrant performed best (table 48) and performed significantly better than the Wholist/Imager quadrant that performed least well (table 50).

The significant difference in the performance of the CS quadrants show that in complex tasks it is not possible to make reliable predictions of performance for individuals based on their Wholist-Analytic classification without reference to their Verbal-Imagery classification. Different aspects of complex tasks may be suitable for different dimensions e.g. the A_PNC task is expected to be suitable for Wholists because an understanding of the information depends on the order in which the information is presented, and are also expected to be suitable for Verbalisers because the information is presented using words. Therefore it is more difficult to accurately predict performance (e.g. Analytics may perform well if they are Verbalisers and Imagers may perform well if they are Wholists).

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
A_OBJ * A_CON	0.04	0.85	0.00	0.05	0.11	0.74	0.00	0.06
A_PNC * A_PWC	3.96	0.05	0.08	0.50	12.12	0.00	0.21	0.93

Table 51: Audio test tasks two-way ANOVA

A two-way ANOVA calculation was performed to compare the performance of subjects between two tasks that were expected to be performed differently by subjects of particular CS groups to test whether the difference in performance of CS groups in one task is matched by a corresponding opposite difference in the other task. The performance of subjects in the A_OBJ task (that was expected to be performed better by Imagers) was compared against the performance of subjects in the A_CON task (that was expected to be performed better by Imagers) and the performance of subjects in the A_PNC task (that was expected to be performed better by Wholists) was compared against the performance of subjects in the A_PWC task (that was expected to be performed better by Analytics). No significant effect was detected in the comparison of the A_OBJ task and the A_CON task. As in the text test this may be because there were relatively few questions asked in each task compared to the CSA test.

Interactions between performance and CS were detected in the comparison of two types of *procedural* tasks. A marginally significant interaction between performance and the Wholist-Analytic classification of subjects was detected for the A_PNC task and the A_PWC task (p=0.05, table 51). This result is supported by the relatively high Eta squared figure of 0.08 and the observed power figure of 0.50. Wholists were expected to perform better than Analytics in the questions that did not require subjects to perform calculations and although Analytics performed both tasks better than Wholists the relative performance of Wholists was better in this task (89.63% of the Analytics PR, table 48) than in the questions that did require subjects to perform calculations (80.60% of the Analytics PR, table 48).

A stronger interaction was detected for the Verbal-Imagery dimension. Significant and marginally significant interactions were detected between performance and the Verbal-Imagery dimension (p=0.00). These findings are supported by the relatively high F statistic (12.12), Eta squared (0.21) and the observed power (0.93) values.

6.5.2 Results of the audio test by style of task

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
A_W	8	10.01 (2.52)	9.42 (2.48)	10.51 (2.48)	10.44 (2.51)	9.70 (2.52)	10.26 (2.48)	8.77 (2.37)	10.60 (2.65)	10.45 (2.45)
A_A	5	8.85 (2.90)	8.63 (2.92)	9.04 (2.92)	10.01 (3.14)	8.02 (2.43)	9.32 (3.62)	8.11 (2.26)	10.64 (2.65)	7.94 (2.64)
A_V	17	9.79 (1.85)	9.41 (1.71)	10.11 (1.93)	10.48 (1.66)	9.29 (1.85)	10.08 (1.57)	8.90 (1.69)	10.85 (1.72)	9.61 (1.96)
A_I	45	11.48 (1.79)	11.49 (2.04)	11.47 (1.58)	10.92 (1.95)	11.88 (1.57)	10.92 (2.23)	11.92 (1.85)	10.92 (1.77)	11.84 (1.37)

Table 52: Audio task styles mean results

In the audio Wholist tasks (A_W) the Wholists were expected to perform better than Analytics however the Analytics performed better than Wholists and subjects in Analytic quadrants performed better than subjects in Wholist quadrants (table 52). As expected Analytics performed the Analytic tasks (A_A) better than Wholists (table 52). The Verbalisers also performed the Analytic tasks well with subjects in Verbaliser quadrants performing better than subjects in Imager quadrants (table 52).

In the audio Verbaliser tasks (A_V) the Verbalisers were expected to perform better than Imagers and did perform better than Imagers and subjects in Verbaliser quadrants achieved higher mean PRs than subjects in Imager quadrants (table 52). As expected Imagers performed the Imager tasks (A_I) better than Verbalisers and subjects in Imager quadrants achieved higher PRs than subjects in Verbaliser quadrants (table 52).

The one-way ANOVA calculations identify one marginally significant and two significant interactions between performance and the CS of subjects (table 53). In the Analytic tasks a significant interaction between PR and the Verbal-Imagery classification of subjects (p=0.02, table 53) was detected. This result was supported by the relatively high Eta squared value of 0.12 and the relatively high observed power figure of 0.67. Verbalisers performed the Analytic tasks better than the Imagers (table 52). The Analytic style tasks comprised the A_MAT and A_PWC tasks that were also both suitable for Verbalisers, therefore it is not surprising that Verbalisers performed these tasks significantly better than Imagers.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
A_W	2.02	0.16	0.04	0.29	1.32	0.26	0.03	0.20
A_A	0.52	0.47	0.01	0.11	5.98	0.02	0.12	0.67
A_V	2.11	0.15	0.04	0.30	5.72	0.02	0.11	0.65
A_I	0.01	0.93	0.00	0.05	3.53	0.07	0.07	0.45

Table 53: Audio task styles one-way ANOVA

In the Verbaliser tasks a significant interaction between performance and the Verbal-Imagery classification of subjects (p=0.02, table 53) was detected. This result was supported by the relatively high F statistic of 5.72, the relatively high Eta squared value of 0.11 and the relatively high observed power figure of 0.65. In the Imager tasks a marginally significant interaction between PR and the Verbal-Imagery classification of subjects (0.07) was detected. This result was supported by the relatively high Eta squared value of 0.07 and the relatively high observed power figure of 0.45. The performance of the Imager tasks was as expected (table 52). The Verbaliser tasks were performed best by Verbalisers and the Imager tasks were performed best by Imagers (table 52) which was as expected.

A marginally significant difference was detected in the performance of the two of the CS quadrants in the Analytic tasks and a significant difference was detected in the performance of the two of the CS quadrants in the Verbaliser tasks.

Table 54 shows the results of the Tukey calculations for the Analytic and Verbaliser style tasks. There was a marginally significant difference in the performance of Analytic/Verbalisers and Analytic/Imagers in the Analytic tasks (p=0.08, table 54). Analytic/Verbalisers performed the task best while Analytic/Imagers performed least well (table 52). This reflects the influence of the other dimension in the performance of tasks that were designed to suit one CS group. The Analytic tasks were also expected to suit Verbalisers and the aspects of the tasks that suited Verbalisers influenced performance more than the aspects that suited Analytics.

		A_A	A_V
Wholist/Verbaliser	Wholist/Imager	0.73	0.39
	Analytic/Verbaliser	0.70	0.75
	Analytic/Imager	0.61	0.91
Wholist/Imager	Wholist/Verbaliser	0.73	0.39
	Analytic/Verbaliser	0.13	0.05
	Analytic/Imager	1.00	0.71
Analytic/Verbaliser	Wholist/Verbaliser	0.70	0.75
	Wholist/Imager	0.13	0.05
	Analytic/Imager	0.08	0.29
Analytic/Imager	Wholist/Verbaliser	0.61	0.91
	Wholist/Imager	1.00	0.71
	Analytic/Verbaliser	0.08	0.29

Table 54: Audio task styles Tukey results

In the Verbaliser tasks there was a significant difference in the performance of Analytic/Verbalisers and Wholist/Imagers (p=0.05, table 54). Analytic/Verbalisers performed the task best while Wholist/Imagers performed least well (table 52). This was as expected as Verbalisers were expected to perform better than Imagers and as the Verbaliser tasks contained tasks that were expected to suit Analytics the Analytics were expected to perform better than Wholists.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
A_W * A_A	2.03	0.16	0.04	0.29	6.17	0.02	0.12	0.68
A_V * A_I	0.80	0.38	0.02	0.14	0.11	0.74	0.00	0.06

Table 55: Audio task styles two-way ANOVA

The performance of subjects in the Wholist style questions were compared with the performance of subjects in the Analytic style questions and the performance of subjects in the Verbaliser style questions were compared against the performance of subjects in the Imager style questions (table 55).

In the comparison of the performance in the Wholist and Analytic tasks a significant interaction was detected between PR and subjects' Verbal-Imagery classification (p=0.02, table 55). This result was supported by the relatively high F statistic figure of 6.17, the relatively high Eta squared value of 0.12 and the relatively high observed power figure of 0.68. This result reinforces the effect identified by the Tukey calculations for the Analytic tasks, as the Verbal-Imagery classification of subjects had more of an influence on performance than their Wholist-Analytic classification. Verbalisers performed the Analytic tasks significantly better than Imagers while there was no significant difference between the performance of Analytics and Wholists.

6.5.3 Summary of the results of the audio test

The results of the audio task produced more evidence than the other media tests to examine the hypothesis that performance of the CS groups can be predicted when using the same media or the same parts of the brain as the CSA test. Most of the simple tasks were not performed significantly different by any of the CS groups, but there were significant differences shown up in the more complex tasks (A_PRO, A_PWC and A_2IN) and in tasks that were grouped together by the CS of task (Analytic, Verbaliser and Imager style tasks).

More significant differences were detected between Verbalisers and Imagers than between Wholists and Analytics. Where a marginal significant difference was detected between Wholists and Analytics in the A_PRO task a more significant difference was detected between Verbalisers and Imagers.

Table 56 summaries the relative performance of the CS groups in the tasks where a significant or marginally significant interaction between performance and CS was detected. None of these tasks were performed in a manner that was opposite to predicted, although significant differences were also detected where no differences were predicted (labelled neutral in table 56).

The complexity of tasks and the influence of both dimensions of CS were identified as factors that made it difficult to accurately predict the relative performance of the CS groups. Where a task contains aspects that suit one CS group in one dimension and other factors that suit another CS in the other dimension it is not possible predict the performance of all subjects dependent on their classification on one dimension without reference to their classification on the other dimension.

The performance of the *procedural* tasks gives some support to the hypothesis that the CS groups will perform as predicted when using the same parts of the brain as used in the CSA test. In the tasks that were concerned with processing language the Verbalisers performed significantly better than Imagers. Similarly the A_2IN task that was concerned with processing non-speech information was performed significantly better by Imagers. However, the majority of tasks, including the ones that were similar to the tasks used in the CSA test (the A_CON and A_OBJ tasks) were not performed significantly better by any CS group. As in the text test the main difference that was identified between the audio test tasks and the CSA test tasks were the simplicity of CSA tasks and the number of questions used.

As expected
• **Procedural** - performed best by **Verbalisers**
• **Procedural questions that included calculations** - performed best by **Analytic/Verbalisers**
• **Identification of 1 musical instrument** - performed best by **Imagers**
• **Procedural questions that included calculations** performed marginally significantly different from **Procedural questions that did not include calculations** depending on the **Wholist-Analytic** classification of subjects
• **Analytic tasks** - performed best by **Analytic/Verbalisers**
• **Verbaliser tasks** - performed best by **Analytic/Verbalisers**
Neutral
• **Procedural** - performed best by **Analytics**
• **Procedural** - performed best by **Analytic/Verbalisers**
• **Procedural questions that included calculations** performed significantly different from **Procedural questions that did not include calculations** depending on the **Verbal-Imagery** classification of subjects
Opposite to expected
• None

Table 56: Text/image test summary of results

6.6 Results of the Video test

The video test presented information using a combination of text, images, moving images and audio, and subjects were asked to perform a series of simple tasks based on that information (chapter 5). The results of the video test are presented in the same manner as the other media tests.

6.6.1 Performance of the video test tasks

The results of the CS groups in each of the tasks performed in the video test are shown in table 57. The information is displayed in the same manner as table 27, using the V_ prefix referring to the video test. The tasks are identified as the *general comprehension* task (**V_GCO**), the *detailed comprehension* task (**V_DCO**), the *mathematics* task (**V_MAT**) and the *procedural* task (**V_PRO**). The *comprehension* task is further divided into the *word-based comprehension* task questions (**V_DCV**) and the *non-word-based comprehension* task (**V_DCI**) questions.

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
V_GCO	10	15.62 (4.73)	16.89 (4.71)	14.53 (4.55)	16.51 (5.17)	14.97 (4.36)	17.22 (4.57)	16.64 (4.98)	15.87 (5.81)	13.61 (3.35)
V_DCO	25	7.87 (2.54)	7.96 (2.44)	7.80 (2.66)	8.67 (3.01)	7.29 (1.99)	8.31 (2.48)	7.69 (2.48)	9.00 (3.51)	6.97 (1.50)
V_DCV	12	7.92 (2.95)	8.12 (3.25)	7.74 (2.72)	8.54 (3.30)	7.46 (2.63)	8.07 (3.44)	8.16 (3.24)	8.96 (3.27)	6.90 (1.95)
V_DCI	13	7.98 (3.24)	7.98 (3.26)	7.98 (3.28)	8.92 (3.74)	7.30 (2.68)	8.67 (3.44)	7.45 (3.15)	9.14 (4.15)	7.18 (2.34)
V_MAT	3	19.06 (9.06)	19.05 (8.97)	19.06 (9.31)	21.16 (9.61)	17.53 (8.49)	18.84 (10.41)	19.21 (8.14)	23.27 (8.76)	16.17 (8.79)
V_PRO	5	10.43 (4.51)	10.25 (4.81)	10.59 (4.32)	10.38 (4.65)	10.48 (4.49)	9.16 (3.69)	11.10 (5.52)	11.48 (5.30)	9.97 (3.56)

Table 57: Video test mean results

A
W

It was expected that Wholists would perform the V_PRO and V_GCO tasks better than Analytics while Analytics would perform the V_DCO and V_MAT tasks better than Wholists (chapter 5).

The video task appeared to suit Wholists slightly more than Analytics. There was a fairly even spread of tasks the Wholists and Analytics performed best, with Wholists performing best in three, Analytics performing best in two and one task in which the performance of Wholists and Analytics was the same. One of the tasks that Wholists were expected to perform better than Analytics was performed as expected while the other was performed opposite to the prior expectation. Wholists achieved a higher PR than Analytics in the V_GCO task (Wholist PR=16.89, Analytics PR=14.53, table 57) but achieved a lower PR in the V_PRO task (Wholist PR=10.25, Analytics PR=10.59, table 57).

One of the tasks that Analytics were expected to perform better than Wholists was performed as expected while the other was performed opposite to the prior expectation. Analytics achieved a higher PR than

Wholists in the V_MAT task (Wholist PR=19.05, Analytics PR=19.06, table 57) but achieved a lower PR in the V_DCO task (Wholist PR=7.96, Analytics PR=7.80, table 57).

It was expected that Verbalisers would perform the V_DCV, V_MAT and V_PRO tasks better than Imagers while Imagers would perform the V_DCI task better than Verbalisers.

The video test appeared to suit Verbalisers more than Imagers as Verbalisers performed better than Imagers in five out of the six tasks. Two of the tasks that Verbalisers were expected to perform better than Imagers were performed as expected while one task was performed opposite to the prior expectation. In the V_MAT task (Verbalisers PR=21.16, Imagers PR=17.53, table 57) and the V_DCV task (Verbalisers PR=8.54, Imagers PR=7.46, table 57) Verbalisers achieved higher PRs than Imagers, while in the V_PRO task (Verbalisers PR=10.38, Imagers PR=10.48, table 57) Verbalisers achieved lower PRs than Imagers.

The task that was expected to be performed better by Verbalisers was not performed as expected as in the V_DCI task (Verbalisers PR=8.92, Imagers PR=7.30, table 57) achieved a lower PR than Imagers.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
V_GCO	2.68	0.11	0.06	0.36	1.13	0.29	0.02	0.18
V_DCO	0.00	0.99	0.00	0.05	3.43	0.07	0.07	0.44
V_DCV	0.05	0.83	0.00	0.06	1.38	0.25	0.03	0.21
V_DCI	0.01	0.91	0.00	0.05	2.95	0.09	0.06	0.39
V_MAT	0.07	0.79	0.00	0.06	1.70	0.20	0.04	0.25
V_PRO	3.64	0.06	0.07	0.46	6.51	0.01	0.12	0.70

Table 58: Video test tasks one-way ANOVA

The results of the one-way ANOVA calculations shown in table 58 identified a number of tasks in which there was a significant or marginally significant interaction between performance and CS. There was a marginally significant interaction detected between performance and the Wholist-Analytic classification of subjects in the V_PRO task (p=0.06, table 58). This result is supported by the Eta squared figure of 0.07 and the relatively high observed power figure of 0.46. This task was expected to suit Wholists because understanding the information depended on the order it was presented. The information was presented as a spoken soundtrack that was accompanied with images of a map which would have suited Analytics. The visual aspect of the task appears to have had more of an influence on the performance of subjects than the soundtrack. Analytics performed this task better than Wholists (table 57).

A marginally significant interaction was detected between performance and the Verbal-Imagery classification of subjects in the V_DCO task (p=0.07, table 58). This result was supported by the relatively high Eta squared value of 0.07 and the relatively high observed power value of 0.44. Verbalisers performed better than Imagers (table 57) which was not expected. The V_DCO task contained virtually an equal number of questions that were suitable for Verbalisers and Imagers therefore neither group were expected to perform the task significantly better than the other.

A marginally significant interaction was detected between performance and the Verbal-Imagery classification of subjects in the V_DCI task (p=0.09, table 58). This result was supported by the relatively high Eta squared value of 0.06. Verbalisers performed better than Imagers (table 57) which was opposite to expected. This task was expected to suit Imagers as the questions were concerned with the observation of moving images and not with information that was presented using words. However the questions themselves contained words and the conceptual associations between the objects depicted which may have favoured Verbalisers more than Imagers.

A significant interaction was detected between performance and the Verbal-Imagery classification of subjects in the V_PRO task (p=0.07, table 58). This result was supported by the relatively high values of the F statistic (6.51), Eta squared (0.12) and the observed power (0.70). This result was supported by the relatively high F statistic of 6.51, the Eta squared value of 0.12 and the observed power value of 0.70. Imagers performed better than Verbalisers (table 57) which was not opposite to prior expectation. Imagers like Analytics benefited more than Verbalisers or Wholists from the addition of moving images to the spoken procedural soundtrack.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
V_GCO * V_DCO	1.47	0.23	0.03	0.22	2.30	0.14	0.05	0.32
V_DCV * V_DCI	0.00	0.96	0.00	0.05	3.24	0.08	0.07	0.42

Table 59: Video test tasks two-way ANOVA

The performance of subjects in the V_GCO task (that was expected to be performed better by Wholists) was compared against the performance of subjects in the V_DCO task (that was expected to be performed better by Imagers) and the performance of subjects in the V_DCV task (that was expected to be performed better by Verbalisers) was compared against the performance of subjects in the V_DCI task (that was expected to be performed better by Imagers). No significant effect was detected in the comparison of the V_GCO task and the V_DCO task, however a marginal effect was detected in the comparison of the V_DCV task and the V_DCI task (p = 0.08). This result is supported by the relatively high Eta squared value of 0.07 and the observed power of 0.42. Verbalisers performed better than Imagers in both the V_DCV and V_DCI tasks (table 57) and the wider variation was between the PRs achieved in the V_DCI task which was opposite to expected. Unlike the V_PRO task Verbalisers performed better than Imagers at making observations of video images whether information was presented using words or not.

6.6.2 Results of the video test by style of task

	Questions	ALL	W	A	V	I	WV	WI	AV	AI
V_W	15	13.52 (3.74)	14.22 (3.80)	12.92 (3.64)	14.16 (4.23)	13.06 (3.34)	14.18 (3.66)	14.25 (4.06)	14.13 (4.88)	12.08 (2.31)
V_A	28	8.65 (2.69)	8.75 (2.56)	8.56 (2.85)	9.53 (3.18)	8.01 (2.12)	9.04 (2.63)	8.52 (2.59)	9.98 (3.67)	7.59 (1.61)
V_V	20	9.45 (2.70)	9.52 (2.60)	9.38 (2.83)	10.00 (3.01)	9.04 (2.42)	9.31 (2.76)	9.68 (2.57)	10.63 (3.22)	8.53 (2.24)
V_I	13	7.98 (3.24)	7.98 (3.26)	7.98 (3.28)	8.92 (3.74)	7.30 (2.68)	8.67 (3.44)	7.45 (3.15)	9.14 (4.15)	7.18 (2.34)

Table 60: Video test tasks mean results by style of question

As expected Wholists performed the Wholist tasks (V_W) better than Analytics and subjects in Wholist quadrants performed better than subjects in Analytic quadrants (table 60). In the video Analytic tasks (V_A) Analytics were expected to perform better than Wholists but it was the Wholists who performed the Analytic tasks best (table 60). Verbalisers also performed the Analytic tasks well with subjects in Verbaliser quadrants performing better than subjects in Imager quadrants (table 60).

In the video Verbaliser tasks (V_V) the Verbalisers were expected to perform better than Imagers and did perform better than Imagers (table 60). In the video Imager tasks (V_I) the Imagers were expected to perform better than Verbalisers however Verbalisers performed better than Imagers and subjects in Verbaliser quadrants performed better than subjects in Imager quadrants (table 60).

The results of tasks that were expected to be suited to each CS were grouped together in order to determine whether the performance of the different CS groups were as expected.

	WA				VI			
Dependent Variable	F	Sig.	Eta Squared	Observed Power	F	Sig.	Eta Squared	Observed Power
V_W	1.08	0.30	0.02	0.17	0.86	0.36	0.02	0.15
V_A	0.00	1.00	0.00	0.05	3.72	0.06	0.08	0.47
V_V	0.01	0.91	0.00	0.05	1.28	0.26	0.03	0.20
V_I	0.01	0.91	0.00	0.05	2.95	0.09	0.06	0.39

Table 61: Video test tasks by style of task one-way ANOVA

The one-way ANOVA calculations identify two marginal interactions between performance and the CS of subjects (table 61). In the Analytic tasks a marginally significant interaction between PR and the Verbal-Imagery classification of subjects (p=0.06, table 61) was detected. This result was supported by the relatively high Eta squared value of 0.08 and the relatively high observed power figure of 0.47. Verbalisers performed the Analytic tasks better than Imagers (table 60). The Analytic tasks were also suitable for Verbalisers and so it is not surprising that the Verbalisers performed these tasks significantly better than Imagers. The Analytic tasks contained the V_MAT task that was expected to suit Verbalisers and the V_DCO task that was expected to contain a mixture of Verbaliser and Imager style questions but was performed significantly better by Verbalisers (as discussed above).

In the Imager tasks a marginally significant interaction between PR and the Verbal-Imagery classification of subjects (p=0.09, table 61) was detected. This result was supported by the relatively high Eta squared value of 0.06. Verbalisers performed the Imager tasks (that contained only the V_DCI task) better as discussed above.

	WA				VI			
Dependent Variable	**F**	**Sig.**	**Eta Squared**	**Observed Power**	**F**	**Sig.**	**Eta Squared**	**Observed Power**
V_W * V_A	0.48	0.49	0.01	0.10	2.33	0.13	0.05	0.32
V_V * V_I	0.02	0.90	0.00	0.05	2.87	0.10	0.06	0.38

Table 62: Video test tasks by style of task two-way ANOVA

The performance of subjects in the Wholist style questions were compared with the performance of subjects in the Analytic style questions and the performance of subjects in the Verbaliser style questions were compared against the performance of subjects in the Imager style questions (table 62). In the comparison of the performance in the Verbaliser and Imager tasks a marginally significant interaction was detected between the PR achieved and subjects' Verbal-Imagery classification (p = 0.10, table 62). This result was supported by the relatively high Eta squared value of 0.06. The relative performance of these tasks were opposite to expectations, as although Verbalisers performed both tasks better than Imagers the PRs of Imagers were closer to that of the Verbalisers in the V_DCV task (90.40% of the Verbalisers PRs, table 60) than in the V_DCI task (81.84% of the Verbalisers PRs, table 60).

6.6.3 Summary of the results of the video test

The video presentation was more complex than the other media tests as a number of different modes of presentation were used simultaneously. Each mode contained aspects that were suitable for different CS groups which made it difficult to predict which CS group would perform best. In the V_PRO tasks the Wholists were expected to perform best due to the procedural presentation of information using speech. The video also contained images of a map which would have suited and contributed to the Analytics performing the tasks better than Wholists. The V_PRO task was also expected to suit Verbalisers than Imagers but Imagers performed the task better than Verbalisers. This suggests that Analytics and Imagers respond better to the addition of images to a spoken soundtrack than Wholists or Verbalisers do.

There was more evidence for significant differences between Verbalisers and Imagers than between Wholists and Analytics (table 63):

- Where there was a marginal significant difference between the performance of Wholists and Analytics there was a significant difference between Verbalisers and Imagers.

- There was a marginally significant difference in performance between the performance of the Analytics style tasks even when there was no significant difference between Wholists and Analytics.
- There was a significant difference between the performance of Verbalisers and Imagers in the V_DCI and V_DCV tasks.

As expected
None
Neutral
Detailed comprehension - performed best by **Verbalisers**
Opposite to expected
Procedural - performed best by **Analytics**
Word-based comprehension - performed best by **Imagers**
Non-word-based comprehension - performed best by **Verbalisers**

Table 63: Video test summary of results

6.7 Summary of results

A hypothesis was developed from examining the background information to the problem (chapter 5):

- A persons' cognitive style will affect their performance in a predictable manner when performing tasks that use the same media that are used in the CSA.
- A persons' cognitive style will affect their performance in a predictable manner when processing information using the same parts of the brain that were used during the CSA test.
- A persons' cognitive style will not affect their performance in a predictable manner when processing information using different parts of the brain than were used during the CSA test.

The experiment tasks were designed with aspects that suited different CS styles. Each CS group was expected to perform tasks that suited them significantly better than the opposite CS group. However few tasks (10 out of a total of 33 tasks) showed any significant or marginally significant interactions between performance and CS.

Overall there were relatively few tasks in which there was a significant interaction between performance and the CS of subjects which means for most tasks there will be no expected difference in the performance of the CS groups.

When comparing performance in the tasks that were directly comparable with the CSA test and used the same media as the CSA test there was no evidence to support the hypothesis:

- In the image test *comparison of objects* task (similar to the CSA Wholist style questions) there was no significant interaction between performance and CS.
- In the image test *comparison of physical attributes of objects* task (similar to the CSA Analytic style questions) there was a marginally significant interaction between performance and CS. Wholists performed this task better than Analytics, which was opposite to prior expectations.
- In the text test *comparison of concepts* task (similar to the CSA Verbaliser style questions) there was no significant interaction between performance and CS.
- In the text test *comparison of objects* task (similar to the CSA Imager style questions) there was no significant interaction between performance and CS.

When comparing performance in the other tasks that used the same media as the CSA test only two tasks were found to have a significant or marginally significant interaction between performance and CS. These tasks were performed in an opposite manner to the prior expectation (I_TOB and I_CFG).
When comparing performance in the other tasks that used different media to the CSA test the majority of tasks were not performed significantly different by the CS groups.

- No significant differences were detected between performance and CS in the combined text/image test.
- Two audio tasks were performed as expected (A_PRO and A_2IN) which is evidence against the hypothesis.

- Two video tasks were performed opposite to the expectation (V_DCI and V_PRO) which is evidence supporting the hypothesis.

Type of media appears to have more influence on performance than the structure of information. More significant interactions between performance and CS were found to occur within the Verbal-Imagery dimension than the Wholist-Analytic dimension:

- Where tasks are expected to suit either Wholists or Analytics and Verbalisers or Imagers it is more likely that a difference would be detected between Verbalisers and Imagers. A greater number of significant or marginally significant interactions were detected between Verbalisers and Imagers than between Wholists and Analytics (Wholist-Analytic=4, Verbal-Imagery=14).
- Where a significant or marginally significant difference is detected between Wholists or Analytics there is often also a significant difference between Verbalisers and Imagers (A_PRO, A_PNC * A_PWC, A_A, V_PRO).
- Where a difference between Wholists and Analytics was expected but no difference was detected there is often a significant or marginally significant difference between Verbalisers and Imagers (I_TOB, I_CFG, I_W, I_W * I_A, A_PWC, A_W * A_A, V_DCO).

Verbalisers performed two Imager style tasks better than Imagers in the image test (I_TOB and I_CFG). Verbalisers performed better than Imagers when considering the conceptual associations between the objects whether the objects are given textual labels or are depicted with images.

The tasks in which a significant or marginally significant interaction was detected between performance and CS are summarised in figure 97. The table lists the tasks each CS group performed best (comparing Wholists against Analytics and Verbalisers against Imagers) showing the media and task in which the interaction was detected. The tasks are listed in terms of whether they were performed as predicted before the experiment, opposite to the prediction or whether there was no prior prediction (neutral). This table can be used in order to predict the relative performance of the CS groups when presented with similar tasks.

Wholists

Expected:

- None

Not Expected:

- Image - comparison of Physical attributes of objects

Neutral:

- Text - procedural

Analytic

Expected:

- None

Not Expected:

- Video - procedural

Neutral:

- Audio - procedural

Verbaliser

Expected:

- Audio - procedural
- Audio procedural (no calculations)
- Audio - Verbaliser style
- Video - word-based procedural
- Video - Verbaliser style

Not Expected:

- Image - comparison of types of objects
- Image - configuration
- Video - non-word-based comprehension
- Video - Imager style

Neutral:

- Image - Wholist style
- Audio - Analytic style
- Video - detailed comprehension
- Video - Analytic style

Imager

Expected:

- Audio - identification of 2 instruments
- Audio - Imager

Not Expected:

- Video - procedural

Neutral:

- None

Figure 97: Tasks best suited to cognitive style groups

Results of the Tukey calculations show that there were few tasks in which the performance of the CS quadrants were significantly different. This may be because there were relatively few subjects in each quadrant compared to the overall CS groups. The tasks in which the performance of the CS quadrants were significantly different highlight the influence that both dimensions had on performance (e.g. tasks that are expected to suit Analytics and Verbalisers may not suit Analytics who are Imagers or Verbalisers who are Wholist). Table 95 summarises the tasks in which the performance of two CS quadrants were significantly different. The tasks each quadrant performed best is listed in the suitable section while the quadrant that was performed worst is listed in the Not Suitable section.

Analytic/Verbaliser

Suitable:

- Image - configuration
- Audio - procedural
- Audio - procedural (with calculations)
- Audio - Analytic style
- Audio - Verbaliser style

Not Suitable:

- None

Analytic/Imager

Suitable:

- None

Not Suitable:

- Image - configuration
- Audio - Analytic style

Wholist/Verbalisers

Suitable:

- None

Not Suitable:

- None

Wholist/Imagers

Suitable:

- None

Not Suitable:

- Audio - procedural
- Audio - Verbaliser style

Figure 98: Tasks best suited to cognitive style quadrants

There may be a number of reasons why the results of the experiments were not as expected:

1. The number of questions used in the experiment. The CSA test uses a large number of questions to assess the performance of each CS group while this experiment used a smaller number of questions in each task. The difference in performance may only be revealed after a large number of questions.
2. The relative number of Wholist-Analytic style questions compared to the number of Verbal-Imagery questions. There were more Verbal-Imagery style questions used in the experiment than Wholist-Analytic questions. It is more difficult to identify the style of questions that would be suitable for Wholists or Analytics.
3. The complexity of the tasks used in the experiment. The CSA test used simple tasks that contained aspects that were suitable only for one CS group. This experiment used a range of tasks that included more complex tasks. Complex tasks may contain a number of aspects that may suit different CS groups e.g. the *procedural* task that contain calculations may be suitable for Wholists as the information is presented in a procedural manner, but it may also be suitable for Analytics as it contains a mathematical aspect. Where complex tasks contain aspects that are suitable for different dimensions it may not be possible to predict which has the stronger influence on performance.
4. The measurement of performance. The CSA test uses questions that are targeted specifically at one CS style with another set targeted at the opposite style of task. Performance is measured as the difference in performance of individuals between the two styles of task, while this experiment measured the difference in performance of the CS groups within each task.

It is not possible to reject the hypothesis as the majority of tasks did not reveal any significant differences between performance and CS. There were few tasks in which there was a significant interaction between performance and CS. The low observed power figures throughout the experiment indicate that there is a possibility of a type II error if the hypothesis was rejected.

There is a need to examine the performance of subjects in more simple tasks using a larger number of questions with a measurement that directly compares the performance of subjects in one style of task using one media against the opposite style of task. Chapter 8 describes a third experiment that is concerned with this question.

Although the media tests did not prove or disprove the hypothesis the results of each media test can be used in order to predict the relative performance of each CS group performing similar tasks with the same types of media. The mean results tables identify which CS groups are expected to perform best and the tables showing the results of the ANOVA calculations identify the tasks where the performance of the CS groups were significantly different. The next chapter develops the examination of the relative performance of the CS groups by examining the relative performance of the CS groups between the tasks within the media tests and the performance in individual tasks between the different media.

7 The relative performance of cognitive style groups in the tasks performed in the media tests

The aim of this chapter is to derive recommendations for designing user interfaces which improve the performance of users with different cognitive styles (CS) from the results of the media tests. Chapter 6 discussed the results of the tests in terms of whether the performance of the different CS groups were as expected while this chapter discusses the relative performance of subjects between the tasks carried out both within each media test and between the tests.

By identifying the tasks in which the subjects achieved high performance it is possible to derive general recommendations for developers of multimedia computer interfaces. Where CS is shown to affect the performance of subjects there is a potential benefit in adapting computer interfaces to suit the CS of users. The tables presented in this chapter show the relative performance of each CS group between the tasks for each media. These tables can be used by developers of multimedia systems to select the optimal tasks and media to present to users of each CS group.

The relative performance of subjects between each task was assessed by performing t-tests comparing the distribution of subjects' performance in one task against another task. This was repeated for all combinations of task in each CS group. The t-tests identified the pairs of task in which there was a significant or marginally significant difference in performance. Recommendations to improve the performance of users can be made by examining the results of the t-tests. If the t-test indicated that there were significant differences in the performance of two tasks then the recommendation is that activities should be designed in a manner that are similar to the tasks that were performed better. If the t-test indicated that there was no significant difference in the performance of the two tasks then the recommendation is that tasks should be designed in a manner that is similar to either task.

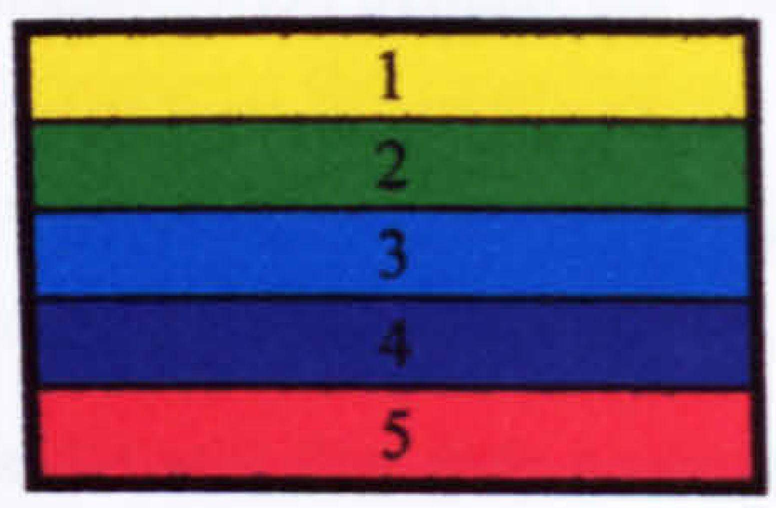
The first half of this chapter compares the relative performance between the tasks performed in each media test. The performance in all the tasks are ranked for each CS group within each media test. Although the identification of the relative performance of tasks gives an indication of the types of task that will be performed well when information is presented using one media type this cannot determine which type of media is best suited for each task. This is examined in the second half of the chapter by comparing the performance of each task between each media. For each CS group the tasks are ranked by performance.

7.1 Comparison of performance of tasks within each media test

The performance of each CS group was compared between the tasks that were performed within each media test. All tasks are ranked including the tasks that are subsets of other tasks. The *procedural* task (PRO) is divided into type of question and treated as separate tasks, including the questions that involved calculations (PWC), and the questions that did not include calculations (PNC). Similarly the video test *detailed* *comprehension* task (V_DCO) is divided between the questions that were expected to suit Verbalisers (V_DCV) and the questions that were expected to suit Imagers (V_DCI).

The tables that follow show the ranking of the tasks performed in each media test for each CS group. Tasks are ranked against each other by the performance ratios (PR) achieved by each CS group (shown in chapter 6). The tasks are ordered in rows reflecting the ranking of the ALL subjects column (all subjects regardless of CS). The rank number is shown for each CS group. Where the results of the t-test indicate that there was no significant difference or marginally significant difference in the performance of tasks both tasks are placed within the same band (indicated by the coloured bands).

The colours used in the tables reflect the ranking with yellow at the top through to red at the bottom. The following key shows the order in which the colours are used. Note that where a number of tasks are placed in the same band there may be no tasks in the lower bands.



Key to the tables indicating rank

A task is placed in the same band as all tasks which were not performed significantly differently from itself. It is possible that two tasks that were performed significantly differently would be placed within the same band if they were not performed significantly differently to a third task.

Developers of multimedia systems using these tables can expect that there will be no difference in performance when users are presented with tasks that appear in the same coloured band while there would be a measurable difference between tasks within different coloured bands.

The relative performance of the CS groups between the tasks are discussed by comparing the nature of the tasks and whether the relative differences between the CS groups can be explained by their expected performance (as described in chapter 5).

7.1.1 Comparison of performance in the text test

The performance of the CS groups are compared between all of the individual tasks and also between the tasks grouped by the CS that they were expected to suit.

Table 64 shows the significance values of the t-tests comparing the PRs achieved in each task performed in the text test. Separate calculations were performed for each CS group in all combinations of task pairs.

The columns identify subjects divided among all the CS categories: all subjects regardless of CS (**ALL**), the Wholist-Analytic dimension regardless of Verbal-Imagery classification including Wholists (**W**) and Analytics (**A**), the Verbal-Imagery dimension regardless of Wholist-Analytic classification, including Verbalisers (**V**) and Imagers (**I**), and the CS quadrants formed by combining the Wholist-Analytic and Verbal-Imagery dimensions, including Wholist/Verbalisers (**WV**), Wholist/Imagers (**WI**), Analytic/Verbalisers (**AV**) and Analytic/Imagers (**AI**).

	ALL	W	A	V	I	WV	WI	AV	AI
T_CON * T_OBJ	0.33	0.57	0.40	0.81	0.26	0.94	0.32	0.53	0.57
T_MAT * T_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_PRO * T_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_PNC * T_OBJ	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00
T_PWC * T_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_MAT * T_CON	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
T_PRO * T_CON	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_PNC * T_CON	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.02	0.00
T_PWC * T_CON	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_COM * T_CON	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
T_PRO * T_MAT	0.00	0.09	0.00	0.06	0.00	0.46	0.13	0.03	0.00
T_PNC * T_MAT	0.69	0.55	0.27	0.15	0.18	0.52	0.83	0.09	0.06
T_PWC * T_MAT	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00
T_COM * T_MAT	0.00	0.02	0.05	0.16	0.01	0.21	0.07	0.50	0.06
T_PNC * T_PRO	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.20
T_PWC * T_PRO	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.17
T_COM * T_PRO	0.03	0.94	0.00	0.53	0.03	0.81	0.68	0.14	0.01
T_PWC * T_PNC	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.18
T_COM * T_PNC	0.10	0.03	0.96	0.03	0.80	0.17	0.10	0.09	0.19
T_COM * T_PWC	0.00	0.01	0.00	0.01	0.00	0.39	0.00	0.01	0.00

Table 64: Results of t-tests comparing performance of the tasks in the text test

The tasks are identified in the same manner as in chapter 6 e.g. T_CON * T_OBJ refers to the t-test performed on the PR figures of the text test *comparison of concepts* task (T_CON) compared to the text test *comparison of objects* task (T_OBJ). All the other combinations of pairs of tasks are shown in the other rows.

A significance figure of less than 0.05 indicates that the performance of subjects in the two tasks was significantly differently (these are highlighted with yellow in the table). Significance figures of between 0.05 and 0.10 indicates that there was a marginally significant difference in the performance of the two tasks (these are highlighted with green in the table). Where the significance values are greater than 0.10 there was no significant difference between the performance of both tasks (these have a white background in the table).

	ALL	W	A	V	I	WV	WI	AV	AI
T_OBJ	1	1	1	1	1	2	1	1	1
T_CON	2	2	2	2	2	1	2	2	2
T_MAT	3	4	3	4	3	4	4	4	3
T_PNC	4	3	4	3	4	3	3	3	5
T_COM	5	5	5	5	5	6	5	5	4
T_PRO	6	6	6	6	6	5	6	6	6
T_PWC	7	7	7	7	7	7	7	7	7

Table 65: Ranking of tasks by performance in the text test

Table 65 shows the ranking of tasks by the PRs achieved in the text task for each of the CS groups. The table shows two main features, the numbers indicating rank of tasks and the coloured bands that group tasks that were not performed significantly differently.

The ranking numbers are based on the mean PRs presented in chapter 6. The mean results for the text test are shown in table 27. The rows list the tasks in order of the ranking for ALL subjects regardless of their CS. The tasks are ranked from highest PR, the *comparison of objects* task (T_OBJ) with a PR of 18.07, to lowest, the *procedural* task questions that included calculations (T_PWC) with a PR of 3.61. The other columns show the rankings for all other categories of CS. The rankings in the other columns follow the overall trend of the ALL column but there are slight variations between CS groups.

The coloured bands on table 65 indicate which tasks were performed significantly differently. Where the t-test indicates that there was a significant or marginally significant difference in performance between two tasks (shown in table 64) both tasks are placed within the same coloured band.

The ranking of the ALL subjects column reflected the activities subjects have to perform while the difference between the CS groups reflects the relative strengths and weaknesses of each CS group. The tasks that subjects performed best were the most simple, while the tasks that all subjects did not perform as well were progressively more complex.

- The top two tasks were the simplest; the *comparison of concepts* task (T_CON) and the *comparison of objects* (T_OBJ) task both required subjects to consider the associations between two words. There was no significant difference in the performance of these two tasks either between the CS groups (chapter 6) or between the two tasks.
- The next two tasks involved different activities but were of equivalent complexity. The *mathematics* task (T_MAT) required subjects to perform simple calculations and the *procedural* task questions that did not

include calculations (T_PNC) required subjects to recall information in the order that it was presented. The next ranked task the *comprehension* task was similar to the *procedural* task questions that did not include calculations except that subjects had to place their own structure on the information that was being presented.

- The next ranked task the *procedural* task (T_PRO) was a combination of the *procedural* task questions that did not include calculations (T_PNC) that was ranked higher and the more complex questions that did include calculations (T_PWC) that was ranked lower.
- The task ranked at the bottom, the *procedural* task questions that did include calculations (T_PWC) was the most complex task as subjects had to recall information in the order it was presented and perform calculations with the information.

The difference between the relative performance of Wholists and Analytics can be explained by the expected performance of the tasks. Analytics performed the *comprehension* task (T_COM) significantly better than the *procedural* task (T_PRO) while Wholists did not. This can be explained as the *comprehension* task was expected to suit Analytics rather than Wholists and Analytics did perform this task relatively better than the *procedural* task that contained questions that were suited to both Wholists and Analytics.

Imagers performed the *comprehension* task significantly better than the *procedural* task while Verbalisers did not. While there was no prior expectation for Imagers to perform one task better than the other both tasks were expected to suit Verbalisers and there was no significant difference in performance between the tasks by Verbalisers.

The Analytic/Verbalisers column shows a reversal of order as the *mathematics* task is placed within a lower band than the *procedural* task questions that do not include calculations (T_PNC). This is unusual as this does not occur in any other CS group and the *mathematics* task was expected to suit both Analytics and Verbalisers while the *procedural* task questions that do not include calculations were expected to suit Wholists and Verbalisers.

	ALL	W	A	V	I	WV	WI	AV	AI
T_W * T_A	0.02	0.01	0.55	0.01	0.54	0.12	0.05	0.01	0.28
T_V * T_I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 66: Results of t-tests comparing performance by style of task in the text test

	ALL	W	A	V	I	WV	WI	AV	AI
T_W	1	1	1	1	1	1	1	1	2
T_A	2	2	2	2	2	2	2	2	1
T_I	1	1	1	1	1	1	1	1	1
T_V	2	2	2	2	2	2	2	2	2

Table 67: Ranking of styles of tasks by performance in the text test

Table 67 shows the ranking of the Wholist style tasks compared to the Analytic style tasks and the Verbaliser style task compared to the Imager style tasks. The coloured bands indicate whether the groups of tasks were performed significantly differently from each other and are derived from the results of the t-tests (table 66).

Wholists performed the Wholist tasks significantly better than the Analytic tasks while there was no difference in performance between the styles of task by Analytics. The ranking of the PRs were as expected as Wholists performed the Wholist style tasks significantly better than the Analytic tasks as expected. There was no significant difference between the PRs of Analytics between the two styles of task which also indicates that Analytics performed relatively better than Wholists at the Analytic style tasks.

For all CS groups the Imager style tasks were performed significantly better than the Verbaliser style tasks. There was only one Imager style task, *the comparison of objects* task which was one of the simpler tasks which was performed well in all measures while there was a wider range of Verbaliser style tasks, most of which were performed significantly worse than the Imager style task. In summary, the overall ranking can be explained by the types of activities performed in each task (from simple to complex). The relative difference in performance can be summarised by table 68.

Relative difference between:	**Is performance explained by the expected performance?**
Individual tasks: Wholist-Analytics dimension	YES
Individual tasks: Verbal-Imagery dimension	YES
Style of tasks: Wholist-Analytics dimension	YES
Style of tasks: Verbal-Imagery dimension	NO DIFFERENCES

Table 68: Summary of the text test task comparisons

7.1.2 Comparison of performance in the image test

	ALL	W	A	V	I	WV	WI	AV	AI
I_TOB * I_PhOB	0.00	0.07	0.00	0.00	0.08	0.10	0.33	0.00	0.15
I_OBJ * I_PhOB	0.00	0.48	0.00	0.00	0.03	0.61	0.61	0.00	0.03
I_CFG * I_PhOB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00
I_MAT * I_PhOB	0.90	0.12	0.11	0.84	0.99	0.57	0.08	0.30	0.24
I_OBJ * I_TOB	0.60	0.41	0.98	0.07	0.56	0.28	0.80	0.17	0.31
I_CFG * I_TOB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I_MAT * I_TOB	0.00	0.01	0.05	0.00	0.10	0.06	0.08	0.03	0.61
I_CFG * I_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I_MAT * I_OBJ	0.00	0.12	0.02	0.08	0.03	0.45	0.18	0.09	0.10
I_CFG * I_MAT	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.00

Table 69: Results of t-tests comparing performance of the tasks in the image test

	ALL	W	A	V	I	WV	WI	AV	AI
I_TOB	1	1	2	1	2	1	1	1	2
I_OBJ	2	2	1	2	1	2	2	2	1
I_MAT	3	4	3	3	3	4	4	3	3
I_PhOB	4	3	4	4	3	3	3	4	4
I_CFG	5	5	5	5	5	5	5	5	5

Table 70: Ranking of tasks by performance in the image test

Table 70 shows the tasks ranked by the PRs achieved in the image test for each of the CS groups. The coloured bands that indicate whether the tasks were performed significantly differently were derived from the results of the t-tests (table 69).

As in the text task the ranking of the ALL subjects column reflected the amount of activities each task required subjects to perform:

- The top two ranked tasks were the simplest. The comparison of *types of objects* task (I_TOB) asked subjects to compare two images and determine whether they were the same. The *comparison of objects* task (I_OBJ) presented three objects and asked subjects to select the odd one out.
- The next two tasks ranked lower were more complex. The *mathematics* task (I_MAT) required subjects to identify numbers of a dice and to perform calculations. The *comparison of physical attributes of objects* task (I_PhOB) contained a variety of questions including identifying the largest object, estimating the distance between objects and determining whether one object was contained inside another.
- The task that was ranked lowest was the most complex task. The *configuration* task (I_CFG) required subjects to study a map and recall information.

The performance of Analytics showed a significant difference between *the comparison of objects* task (I_OBJ) and the *mathematics* task (I_MAT). Both of these tasks were expected to suit Analytics and so it is not explained why Analytics should achieve significantly lower PRs in these tasks than the top ranked tasks while Wholists did not.

Verbalisers performed the *comparison of types of object* task (I_TOB) significantly differently from the *comparison of objects* task (I_OBJ) while Imagers did not. Both these tasks were expected to suit Imagers and so it was expected that Imagers would not perform these tasks differently while no difference in behaviour was predicted for Verbalisers.

	ALL	W	A	V	I	WV	WI	AV	AI
I_W * I_A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I_V * I_I	0.01	0.28	0.01	0.21	0.01	0.37	0.58	0.42	0.01

Table 71: Results of t-tests comparing performance by style of task in the image test

	ALL	W	A	V	I	WV	WI	AV	AI
I_W	1	1	1	1	1	1	1	1	1
I_A	2	2	2	2	2	2	2	2	2
I_V	1	1	1	1	1	1	1	1	1
I_I	2	2	2	2	2	2	2	2	2

Table 72: Ranking of styles of tasks for each measure of performance in the image test

Table 72 shows the ranking of the Wholist style tasks compared to the Analytic style tasks and the Verbaliser style task compared to the Imager style tasks. The coloured bands that indicate whether the groups of tasks were performed significantly differently from each other are derived from the results of the t-tests (table 71).

There was no difference in the performance between the Wholist style tasks (I_W) and the Analytic style tasks (I_A) for any of the CS groups. Only one task was expected to be suitable for Wholists, the *comparison of physical attributes of objects* task (I_PhOB) which was ranked in a middle band (table 70).

Verbalisers performed the Verbaliser style tasks (I_V) significantly better than the Imager style tasks (I_I) while there was no difference in performance by the Imagers. Imagers performed relatively better at the Imager style tasks which resulted in the Verbaliser style tasks not being performed significantly better than the Imager style tasks.

In summary, the overall ranking can be explained by the types of activities performed in each task (from simple to complex). All tasks were performed well by all CS groups except for the relatively more complex *configuration* task. The relative difference in performance between the CS groups can be summarised by table 73.

Relative difference between:	Is performance explained by the expected performance?
Individual tasks: Wholist-Analytics dimension	NO
Individual tasks: Verbal-Imagery dimension	YES FOR IMAGERS, NO FOR VERBALISERS
Style of tasks: Wholist-Analytics dimension	YES
Style of tasks: Verbal-Imagery dimension	YES

Table 73: Summary of the image test task comparisons

7.1.3 Comparison of performance in the text/image test

	ALL	W	A	V	I	WV	WI	AV	AI
TI_PRO * TI_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TI_PNC * TI_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
TI_PWC * TI_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TI_CFG * TI_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TI_MAT * TI_OBJ	0.02	0.03	0.24	0.05	0.16	0.17	0.12	0.20	0.74
TI_PNC * TI_PRO	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.00
TI_PWC * TI_PRO	0.00	0.01	0.00	0.08	0.00	0.07	0.05	0.43	0.00
TI_CFG * TI_PRO	0.12	0.76	0.10	0.46	0.15	0.59	0.30	0.20	0.32
TI_MAT * TI_PRO	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.00
TI_PWC * TI_PNC	0.00	0.00	0.00	0.04	0.00	0.04	0.02	0.31	0.00
TI_CFG * TI_PNC	0.00	0.01	0.00	0.04	0.00	0.48	0.01	0.05	0.00
TI_MAT * TI_PNC	0.00	0.03	0.03	0.02	0.04	0.07	0.20	0.14	0.12
TI_CFG * TI_PWC	0.01	0.04	0.14	0.35	0.01	0.10	0.22	0.93	0.02
TI_MAT * TI_PWC	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.00
TI_CFG * TI_MAT	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00

Table 74: Results of t-tests comparing performance of the tasks in the text/image test

	ALL	W	A	V	I	WV	WI	AV	AI
TI_OBJ	1	1	1	1	1	1	1	1	1
TI_MAT	2	2	2	2	2	2	2	2	2
TI_PNC	3	3	3	3	3	3	3	3	3
TI_PRO	4	4	4	4	4	5	4	4	4
TI_CFG	5	5	5	5	5	4	5	6	5
TI_PWC	6	6	6	6	6	6	6	5	6

Table 75: Ranking of tasks by performance in the text/image test

Table 75 shows the ranking of the PR figures of the tasks performed in the text/image test for each of the CS groups. The coloured bands are derived from the results of the t-tests shown in table 74.

The ranking of the ALL column reflects the relative complexity of the tasks performed in the text/image test.

- The task ranked highest was the most simple task. The *comparison of objects* task (TI_OBJ) required subjects to consider objects depicted by images or words and determine whether they were the same type.
- The task ranked second was relatively more complex. The *mathematics* task (TI_MAT) required subjects to perform simple calculations that were depicted using numbers and symbols.
- The task ranked third was more complex. The *procedural* task questions that did not include calculations (TI_PNC) required subjects to recall information in the order it was presented.
- The fourth ranked tasks were of similar complexity. The *procedural* task (TI_PRO) and the configuration task (TI_CFG) both presented information in the form of maps. The difference was that the order in which the information was presented was important for the former but not the latter.

- The task ranked lowest was relatively more complex as the *procedural* task questions that included calculations (TI_PWC) have the extra activity of performing calculations.

Some of the difference between the relative performance of Wholists and Analytics can be explained by the expected performance while others cannot. There was no significant difference in performance by Analytics between the *configuration* task (TI_CFG) and the *procedural* task questions that included calculations (TI_PWC) while there was for Wholists. This can be explained as the both tasks were expected to suit Analytics. There was no significant difference in performance by Analytics between the *comparison of objects* task (TI_OBJ) and the *mathematics* task while there was for Wholists. This is opposite to the expected performance as the *mathematics* task was expected to suit Analytics and it would be expected that Analytics would perform relatively better at this task rather than the Wholists. Similarly there was no significant difference in performance by Wholists between the *procedural* task (TI_PRO) and the *configuration* task while there was for Analytics. This is opposite to the expected performance as the *configuration* task was expected to suit Analytics and it would be expected that Analytics would perform relatively better at this task rather than the Wholists.

Some of the difference between the relative performance of Verbalisers and Imagers can be explained by the expected performance while others cannot. There was no significant difference in performance by Verbalisers between the *configuration* task and the *procedural* task questions that included calculations while there was for Imagers. This can be explained as the *procedural* task questions that included calculations were expected to suit Verbalisers so the Verbalisers were expected to perform relatively better at this task than Imagers. There was no significant difference in performance by Imagers between the *comparison of objects* task and the *mathematics* task while there was for Verbalisers. This is opposite to the expected performance as the *mathematics* task was expected to suit Verbalisers and it would be expected that Verbalisers would perform relatively better at this task rather than the Imagers.

	ALL	W	A	V	I	WV	WI	AV	AI
TI_W * TI_A	0.00	0.11	0.00	0.19	0.00	0.70	0.10	0.20	0.00
TI_V * TI_I	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.06	0.30

Table 76: Results of t-tests comparing performance by style of task in the text/image test

	ALL	W	A	V	I	WV	WI	AV	AI
TI_W	1	1	1	1	1	1	1	1	1
TI_A	2	2	2	2	2	2	2	2	2
TI_I	1	1	1	1	1	1	1	1	1
TI_V	2	2	2	2	2	2	2	2	2

Table 77: Ranking of styles of tasks by performance in the text/image test

Table 77 shows the ranking of the Wholist style tasks compared to the Analytic style tasks and the Verbaliser style task compared to the Imager style tasks. The coloured bands indicate whether the groups of tasks were performed significantly differently from each other and are derived from the results of the t-tests (shown in table 76).

Wholists performed the Wholist style task (TI_W) significantly better than the Analytic style tasks (TI_A) as expected. Analytics did not perform either style of task significantly better than the other which shows they performed the Analytic style tasks relatively better than the Wholists did.

There was no difference in performance by the Verbalisers or Imagers in the Verbaliser (TI_V) or Imager style tasks (TI_I).

In summary, the overall ranking of the text/image tasks can be explained by the types of activities performed in each task (from simple to complex). The relative difference in performance can be summarised by table 78.

Relative difference between:	**Is performance explained by the expected performance?**
Individual tasks: Wholist-Analytics dimension	ONE IS, TWO ARE NOT
Individual tasks: Verbal-Imagery dimension	ONE IS, ONE IS NOT
Style of tasks: Wholist-Analytics dimension	YES
Style of tasks: Verbal-Imagery dimension	NO DIFFERENCES

Table 78: Summary of the text/image test task comparisons

7.1.4 Comparison of performance in the audio test

	ALL	W	A	V	I	WV	WI	AV	AI
A_CON * A_OBJ	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.32	0.00
A_PRO * A_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
A_PNC * A_OBJ	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00
A_PWC * A_OBJ	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.32	0.00
A_MAT * A_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
A_1IN * A_OBJ	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00
A_2IN * A_OBJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_SFX * A_OBJ	0.00	0.00	0.00	0.01	0.00	0.11	0.00	0.03	0.00
A_PRO * A_CON	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00
A_PNC * A_CON	0.00	0.00	0.01	0.01	0.00	0.16	0.01	0.04	0.07
A_PWC * A_CON	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.53	0.00
A_MAT * A_CON	0.00	0.03	0.00	0.01	0.00	0.12	0.15	0.01	0.01
A_1IN * A_CON	0.00	0.05	0.01	0.01	0.03	0.07	0.42	0.13	0.04
A_2IN * A_CON	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
A_SFX * A_CON	0.33	0.98	0.14	0.19	0.78	0.95	0.94	0.01	0.76
A_PNC * A_PRO	0.00	0.00	0.01	0.31	0.00	0.20	0.00	0.90	0.00
A_PWC * A_PRO	0.01	0.06	0.10	0.93	0.00	0.59	0.01	0.46	0.00
A_MAT * A_PRO	0.03	0.01	0.64	0.63	0.02	0.55	0.01	0.95	0.60
A_1IN * A_PRO	0.19	0.14	0.70	0.53	0.02	0.45	0.01	0.87	0.50
A_2IN * A_PRO	0.00	0.00	0.00	0.00	0.12	0.00	0.27	0.00	0.27
A_SFX * A_PRO	0.00	0.00	0.01	0.03	0.00	0.02	0.01	0.67	0.01
A_PWC * A_PNC	0.00	0.03	0.05	0.86	0.00	0.47	0.00	0.59	0.00
A_MAT * A_PNC	0.74	0.23	0.47	0.96	0.64	0.95	0.09	1.00	0.37
A_1IN * A_PNC	0.92	0.62	0.54	0.30	0.46	0.18	0.09	0.83	0.55
A_2IN * A_PNC	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.05
A_SFX * A_PNC	0.00	0.01	0.15	0.10	0.01	0.10	0.03	0.71	0.16
A_MAT * A_PWC	0.00	0.00	0.11	0.86	0.00	0.36	0.00	0.56	0.00
A_1IN * A_PWC	0.01	0.03	0.19	0.67	0.00	0.99	0.00	0.54	0.01
A_2IN * A_PWC	0.14	0.37	0.25	0.00	0.20	0.04	0.43	0.01	0.33
A_SFX * A_PWC	0.00	0.00	0.01	0.31	0.00	0.07	0.00	0.67	0.00
A_1IN * A_MAT	0.72	0.57	0.98	0.43	0.73	0.38	0.75	0.85	0.84
A_2IN * A_MAT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
A_SFX * A_MAT	0.00	0.05	0.02	0.07	0.02	0.07	0.31	0.66	0.02
A_2IN * A_1IN	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.13
A_SFX * A_1IN	0.01	0.07	0.06	0.08	0.05	0.06	0.55	0.70	0.02
A_2IN * A_SFX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 79: Results of t-tests comparing performance of the tasks in the audio test

	ALL	W	A	V	I	WV	WI	AV	AI
A_OBJ	1	1	1	1	1	1	1	1	1
A_CON	2	2	2	2	2	3	2	2	2
A_SFX	3	3	3	3	3	2	3	4	3
A_MAT	4	4	6	5	5	5	5	5	6
A_PNC	5	6	4	4	6	4	6	5	4
A_1IN	6	5	5	8	4	7	4	8	5
A_PRO	7	7	7	7	7	6	7	7	7
A_PWC	8	8	8	6	9	8	9	3	9
A_2IN	9	9	9	9	8	9	8	9	8

Table 80: Ranking of tasks by performance in the audio test

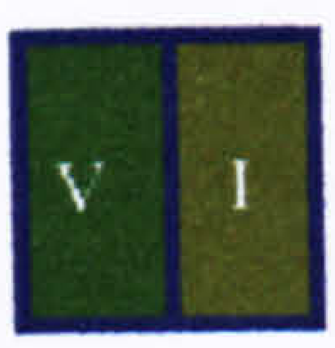
Table 80 shows the ranking of the PR figures of the tasks performed in the audio test for each of the CS groups. The coloured bands are derived from the results of the t-test results shown in table 79.

The relative rankings of the tasks in the ALL column show few significant differences in performance between all the tasks.

- The top ranked task, the *comparison of objects* task (A_OBJ) was one of the most simple task although it was not less complex than the *comparison of concepts* task (A_CON).
- There was no significant difference between the performance of the other tasks which was surprising as there was a wider range of complexity between the tasks.

One factor which may have contributed to the lack of variation was that difference may have been masked by the time spent listening to questions as this was counted in the measurement of duration. Subjects were able to start considering their answer before the question had been read out in full.

The differences between the relative performance of Wholists and Analytics could be explained by the expected performance of tasks. Wholists performed significantly better at the *identification of sound effects* task (A_SFX) than the *mathematics* (A_MAT) task while there was no difference for Analytics. The relative performance of Wholists and Analytics can be explained as the *mathematics* task was expected to suit Analytics and the Analytics did perform the *mathematics* task relatively better than the tasks ranked above unlike the Wholists. Wholists performed significantly better at the *procedural* task (A_PRO) than the *procedural* task questions that included calculations (A_PWC) while there was no difference for Analytics. The relative performance of Wholists and Analytics can be explained as the *procedural* task questions that included calculations were expected to suit Analytics and the Analytics performed the *procedural* task questions that included calculations relatively better than the tasks ranked above unlike the Wholists.



The differences between the relative performance of Verbalisers and Imagers could be explained by the expected performance of the tasks. As expected Imagers performed significantly better at the *identification of sound effects* task that was expected to suit Imagers than the *mathematics* task that was expected to suit Verbalisers, while there was no difference for Verbalisers. As expected Imagers performed significantly better at the *identification of one instrument* task that was expected to suit Imagers than the *procedural* task that were expected to suit Verbalisers, while there was no difference for Verbalisers. Similarly, Verbalisers performed significantly better at the *procedural* task questions that included calculations that were expected to suit Verbalisers than the *identification of two instruments* task that was expected to suit Imagers, while there was no difference for Imagers.

	ALL	W	A	V	I	WV	WI	AV	AI
A_W * A_A	0.03	0.32	0.04	0.65	0.01	0.54	0.44	0.98	0.00
A_V * A_I	0.00	0.00	0.01	0.32	0.00	0.09	0.00	0.92	0.00

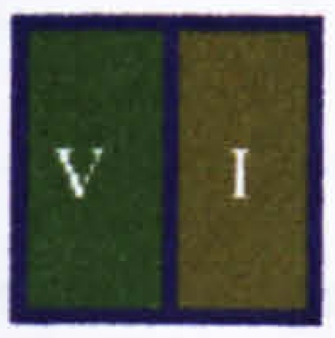
Table 81: Results of t-tests comparing performance by style of task in the audio test

	ALL	W	A	V	I	WV	WI	AV	AI
A_W	1	1	1	1	1	1	1	2	1
A_A	2	2	2	2	2	2	2	1	2
A_I	1	1	1	1	1	1	1	1	1
A_V	2	2	2	2	2	2	2	2	2

Table 82: Ranking of tasks by performance in the audio test

Table 82 shows the ranking of the Wholist style tasks compared to the Analytic style tasks and the Verbaliser style task compared to the Imager style tasks. The coloured bands indicate whether the groups of tasks were performed significantly differently from each other and are derived from the results of the t-tests (shown in table 81).

The Wholists, as expected, achieved significantly higher PRs for the Wholists style tasks than the Analytic style tasks while there was no difference by the Analytics.



Verbalisers unexpectedly achieved significantly higher PRs for the Imager style tasks than the Verbaliser style tasks while there was no difference by the Imagers.

In summary, there were fewer differences in performance detected between tasks for ALL subjects. The relative differences in performance are summarised in table 83.

Relative difference between:	Is performance explained by the expected performance?
Individual tasks: Wholist-Analytics dimension	Yes
Individual tasks: Verbal-Imagery dimension	Yes
Style of tasks: Wholist-Analytics dimension	Yes
Style of tasks: Verbal-Imagery dimension	No

Table 83: Summary of the audio test task comparisons

7.1.5 Comparison of performance in the video test

	ALL	W	A	V	I	WV	WI	AV	AI
V_GCO * V_PRO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01
V_DCO * V_PRO	0.00	0.05	0.00	0.11	0.00	0.55	0.06	0.14	0.00
V_DCV * V_PRO	0.00	0.11	0.00	0.10	0.00	0.51	0.16	0.13	0.00
V_DCI * V_PRO	0.00	0.05	0.00	0.21	0.00	0.76	0.03	0.18	0.00
V_MAT * V_PRO	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.02
V_DCO * V_GCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_DCV * V_GCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_DCI * V_GCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_MAT * V_GCO	0.01	0.31	0.01	0.02	0.16	0.64	0.36	0.00	0.32
V_DCO * V_DCV	0.86	0.72	0.83	0.73	0.61	0.74	0.44	0.92	0.86
V_DCO * V_DCI	0.67	0.96	0.52	0.56	0.98	0.65	0.68	0.74	0.59
V_DCO * V_MAT	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
V_DCI * V_DCV	0.90	0.88	0.66	0.64	0.81	0.69	0.55	0.82	0.72
V_MAT * V_DCV	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
V_DCI * V_MAT	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00

Table 84: Results of t-tests comparing performance of the tasks in the image test

	ALL	W	A	V	I	WV	WI	AV	AI
V_MAT	1	1	1	1	1	1	1	1	1
V_GCO	2	2	2	2	2	2	2	2	2
V_PRO	3	3	3	3	3	3	3	3	3
V_DCI	4	5	4	4	5	4	6	4	4
V_DCV	5	4	6	6	4	6	4	6	6
V_DCO	6	6	5	5	6	5	5	5	5

Table 85: Ranking of tasks by performance in the video test

Table 85 shows the ranking of the PR figures of the tasks performed in the video test for each of the CS groups. The coloured bands are derived from the results of the t-tests shown in table 84.

The relative ranking of the tasks in the ALL column follow the trend from the simplest to the more complex tasks.

- The highest ranked task was the simplest. The *mathematics* task (V_MAT) required subjects to perform simple calculations.
- The next ranked task was more complex. The general *comprehension* task (V_GCO) requires subjects to identify the category of the video clip.
- The task ranked third was more complex. The *procedural* task (V_PRO) required subjects to answer comprehension questions based on the order that information was presented.
- The tasks ranked lowest were the most complex as they depended on the observation of the images and soundtrack of the video clips. The detailed *comprehension* task (V_DCO) including the *non-word-based*

comprehension questions (V_DCI) and the *word-based comprehension* questions (V_DCV) were all performed in a similar manner.

Some of the relative differences between the CS groups are explained by the expected performance while others are opposite to the expected performance. As expected Analytics performed the *mathematics* task (V_MAT) that was expected to suit the Analytics, significantly better than the *general comprehension* task (V_GCO_P) that was expected to suit the Wholists, while there was no difference for Wholists. Analytics performed the *procedural* task that was expected to be suitable for Wholists, significantly better than the *non-word-based comprehension* task (V_DCI) while there was no difference by the Wholists. This was opposite to the expected performance as the Wholists did not perform the task that was expected to be suitable for Wholists significantly better it was not likely that the Analytics would.

As expected Verbalisers performed the *mathematics* task (V_MAT) that was expected to suit the Verbalisers, significantly better than the *general comprehension* task (V_GCO), that was expected to suit either Verbalisers of Imagers, while there was no difference for Imagers. Imagers performed the *procedural* task (V_PRO) that was expected to be suitable for Verbalisers, significantly better than the *non-word-based comprehension* task (V_DCI) that was expected to suit the Imagers, while there was no difference by the Verbalisers. This was opposite to the expected performance by the Imagers in comparison to the Verbalisers.

	ALL	W	A	V	I	WV	WI	AV	AI
V_W * V_A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V_V * V_I	0.00	0.04	0.01	0.14	0.00	0.63	0.01	0.05	0.10

Table 86: Results of t-tests comparing performance by style of task in the video test

	ALL	W	A	V	I	WV	WI	AV	AI
V_W	1	1	1	1	1	1	1	1	1
V_A	2	2	2	2	2	2	2	2	2
V_V	1	1	1	1	1	1	1	1	1
V_I	2	2	2	2	2	2	2	2	2

Table 87: Ranking of styles of tasks for each measure of performance in the video test

Table 87 shows the ranking of the Wholist style tasks compared to the Analytic style tasks and the Verbaliser style task compared to the Imager style tasks. The coloured bands indicate whether the groups of tasks were performed significantly differently from each other and are derived from the results of the t-tests (shown in table 86).

There were no differences between the performance of the Wholist style tasks and the Analytic style tasks by all CS groups.

The relative differences in performance between the Verbalisers and Imagers were as expected. Verbalisers achieved significantly higher PRs for the Verbaliser style tasks than the Imager style tasks while there was no difference in performance by the Imagers.

In summary, the overall rankings of the task reflect the number of activities involved in the tasks (from simple to complex). The relative difference in performance of the CS groups can be summarised by table 88.

Relative difference between:	Is performance explained by the expected performance?
Individual tasks: Wholist-Analytics dimension	One is, one is not
Individual tasks: Verbal-Imagery dimension	One is, one is not
Style of tasks: Wholist-Analytics dimension	No
Style of tasks: Verbal-Imagery dimension	Yes

Table 88: Summary of the video test task comparisons

7.2 Comparison of performance of tasks within each media experiment

For each CS group the performance of subjects was compared between each of the different versions of the tasks performed in the tests. By performing these tests it is possible to determine which media each CS group performs best with for each type of task.

In general Verbalisers were expected to perform relatively better than Imagers when using text while Imagers were expected to perform relatively better when using images than Verbalisers. There is an added complication that tasks using the high-imagery words such as the text *comparison of objects* task are expected to suit Imagers. There was no prior expectation of which media would suit Wholists or Analytics.

7.2.1 Performance of the comparison of concepts task

	ALL	W	A	V	I	WV	WI	AV	AI
T_CON * A_CON	0.00	0.00	0.00	0.02	0.00	0.08	0.00	0.12	0.01

Table 89: Results of t-tests comparing performance of the comparison of concepts tasks

	ALL	W	A	V	I	WV	WI	AV	AI
T_CON	1	1	1	1	1	1	1	1	1
A_CON	2	2	2	2	2	2	2	2	2

Table 90: Ranking of comparison of concepts tasks performance between media

Table 90 shows the ranking of the *comparison of concepts* tasks between the text and audio tests. The coloured bands are derived from the t-tests shown in table 89. The rank number shows which media was performed best while the band indicates whether performance was significantly different from the other media version.

The *comparison of concepts* task used words therefore there were only textual and auditory versions of the task. None of the CS groups performed significantly better using either text or audio.

7.2.2 Performance of the comparison of objects task

	ALL	W	A	V	I	WV	WI	AV	AI
I_OBJ * T_OBJ	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.03
TI_OBJ * T_OBJ	0.00	0.02	0.03	0.14	0.01	0.23	0.06	0.45	0.05
A_OBJ * T_OBJ	0.00	0.01	0.01	0.02	0.01	0.24	0.03	0.01	0.22
TI_OBJ * I_OBJ	0.00	0.00	0.16	0.00	0.08	0.09	0.02	0.01	0.87
A_OBJ * I_OBJ	0.00	0.00	0.04	0.01	0.00	0.01	0.02	0.36	0.07
TI_OBJ * A_OBJ	0.77	0.91	0.62	0.31	0.16	1.00	0.84	0.11	0.07

Table 91: Results of t-tests comparing performance of the comparison of objects tasks

	ALL	W	A	V	I	WV	WI	AV	AI
T_OBJ	1	1	1	1	1	1	1	1	1
A_OBJ	2	3	2	3	2	2	3	3	2
TI_OBJ	3	2	3	2	3	3	2	2	3
I_OBJ	4	4	4	4	4	4	4	4	4

Table 92: Ranking of comparison of objects tasks performance between media

Table 92 shows the ranking of the performance of the *comparison of objects* task for each CS group for each media. The coloured bands are derived from the t-tests shown in table 91. The coloured bands indicate the difference between the relative performance of the CS groups.

Most CS groups achieved significantly greater PRs when information was presented using text. The exception was Verbalisers who did not have any significant difference in performance for text, audio or text/image. Verbalisers performed best where words were used while there was no variation between Imagers.

7.2.3 Performance of the mathematics task

	ALL	W	A	V	I	WV	WI	AV	AI
I_MAT * T_MAT	0.16	0.61	0.17	0.11	0.70	0.39	0.80	0.18	0.54
TI_MAT * T_MAT	0.00	0.06	0.01	0.02	0.02	0.28	0.13	0.04	0.11
A_MAT * T_MAT	0.15	0.22	0.40	0.08	0.73	0.44	0.35	0.10	0.81
V_MAT * T_MAT	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
TI_MAT * I_MAT	0.01	0.10	0.04	0.13	0.04	0.68	0.09	0.08	0.24
A_MAT * I_MAT	0.95	0.47	0.34	0.98	0.95	0.86	0.09	0.80	0.17
V_MAT * I_MAT	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.03
A_MAT * TI_MAT	0.01	0.25	0.01	0.08	0.05	0.45	0.39	0.12	0.06
V_MAT * TI_MAT	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.11
A_MAT * V_MAT	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02

Table 93: Results of t-tests comparing performance of the comparison of objects tasks

	ALL	W	A	V	I	WV	WI	AV	AI
TI_MAT	1	1	1	1	1	1	1	1	1
V_PRO	2	3	3	4	2	4	2	2	3
I_MAT	3	4	2	2	3	2	5	4	2
A_MAT	4	2	4	3	4	3	3	3	5
T_MAT	5	5	5	5	5	5	4	5	4

Table 94: Ranking of mathematics tasks performance between media

Table 94 shows the ranking of the PRs in the *mathematics* task for each CS group for each media. The coloured bands are derived from the t-tests shown in table 93.

A comparison between the different versions of the *mathematics* task reflect the differences in the methods of presentation. The video version presented a video clip that showed the calculations that were to be performed, therefore subjects were able to start calculating their answer before the interface used to enter their answer was presented and the timer started. This was also true for the audio version. There were no significant differences that could be explained by the different methods of entering the answer, whether by selecting tens and units (as for text and audio), clicking on dice (as for images), selecting from three numbers (as for text/images) or selecting from a long list of numbers (as for video).

A
W

Only Analytics and Imagers achieved significantly higher PRs for one medium than the others, which was text/image.

V I

Verbalisers performed all of the versions that used words and the image version equally well while Imagers performed the text/image version better than all others.

7.2.4 Performance of the procedural and configuration tasks

	ALL	W	A	V	I	WV	WI	AV	AI
I_CFG * T_PRO	0.31	0.56	0.00	0.56	0.41	0.44	0.96	0.02	0.09
TI_PRO * T_PRO	0.04	0.95	0.00	0.46	0.03	0.53	0.51	0.03	0.02
TI_CFG * T_PRO	0.33	0.72	0.07	0.86	0.22	0.66	0.98	0.47	0.06
A_PRO * T_PRO	0.00	0.06	0.00	0.00	0.00	0.19	0.20	0.00	0.00
V_PRO * T_PRO	0.00	0.01	0.00	0.01	0.00	0.43	0.01	0.01	0.00
TI_PRO * I_CFG	0.09	0.41	0.13	0.63	0.09	0.92	0.37	0.61	0.14
TI_CFG * I_CFG	0.81	0.59	0.41	0.57	0.81	0.36	0.97	0.22	0.74
A_PRO * I_CFG	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00
V_PRO * I_CFG	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.05	0.00
TI_CFG * TI_PRO	0.12	0.76	0.10	0.46	0.15	0.59	0.30	0.20	0.32
A_PRO * TI_PRO	0.00	0.01	0.01	0.00	0.03	0.01	0.43	0.13	0.03
V_PRO * TI_PRO	0.00	0.00	0.01	0.01	0.00	0.03	0.04	0.13	0.02
A_PRO * TI_CFG	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.01	0.00
V_PRO * TI_CFG	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.00	0.00
A_PRO * V_PRO	0.08	0.13	0.36	0.80	0.04	0.76	0.06	0.63	0.41

Table 95: Results of t-tests comparing performance of the procedural and configuration tasks

	ALL	W	A	V	I	WV	WI	AV	AI
V_PRO	1	1	1	1	1	2	1	1	1
A_PRO	2	2	2	2	2	1	2	2	2
TI_PRO	3	4	3	3	3	5	3	3	3
I_CFG	4	6	4	4	5	6	6	4	5
TI_CFG	5	5	5	5	4	4	5	5	4
T_PRO	6	3	6	6	6	3	4	6	6

Table 96: Ranking of procedural & configuration tasks performance between media

Table 96 shows the ranking of performance in the *procedural* and *configuration* tasks for each CS group in each media test. The coloured bands are derived from the t-tests shown in table 95.

Verbalisers performed the video and audio versions equally well as both used images. Imagers, however performed the video version, that used images, significantly better than the audio version that did not use images.

	ALL	W	A	V	I	WV	WI	AV	AI
TI_PNC * T_PNC	0.68	0.29	0.10	0.31	0.15	0.32	0.67	0.75	0.02
A_PNC * T_PNC	0.14	0.55	0.01	0.97	0.08	0.87	0.54	0.80	0.00
A_PNC * TI_PNC	0.15	0.28	0.36	0.08	0.77	0.07	0.81	0.50	0.56

Table 97: Results of t-tests comparing performance of the procedural task questions that do not include calculations

	ALL	W	A	V	I	WV	WI	AV	AI
A_PNC	1	2	1	1	1	2	3	1	1
TI_PNC	2	3	2	3	2	3	2	3	2
T_PNC	3	1	3	2	3	1	1	2	3

Table 98: Ranking of procedural task questions that do not include calculations performance between media

Table 98 shows the ranking of the PRs of the *procedural* task questions that did not include calculations for each CS group in each media test. The coloured bands are derived from the t-tests shown in table 97.

Wholists, Analytics, Verbalisers and Imagers did not perform any of the different media versions of the *procedural* task questions that did not include calculations significantly differently. This was not surprising, as all versions were similar in structure and presentation.

	ALL	W	A	V	I	WV	WI	AV	AI
TI_PWC * T_PWC	0.87	0.55	0.72	0.71	0.48	0.38	0.89	0.17	0.25
A_PWC * T_PWC	0.00	0.05	0.00	0.00	0.01	0.21	0.12	0.00	0.02
A_PWC * TI_PWC	0.00	0.03	0.01	0.02	0.01	0.06	0.30	0.16	0.02

Table 99: Results of t-tests comparing performance of the procedural task questions that include calculations

	ALL	W	A	V	I	WV	WI	AV	AI
A_PWC	1	1	1	1	1	1	1	1	1
T_PWC	2	2	3	3	2	2	3	3	2
TI_PWC	3	3	2	2	3	3	2	2	3

Table 100: Ranking of procedural with calculations tasks performance between media

Table 100 shows the ranking of the PR measures of the *procedural* task questions that did include calculations for each CS group for each media. The coloured bands are derived from the t-tests shown in table 99.

Wholists, Analytics, Verbalisers and Imagers all performed the audio version of the *procedural* task questions that did include calculations significantly better than the other version of the task. This result was surprising compared to the *procedural* task questions that did not include calculations in which no significant differences were found.

7.2.5 Performance of the comprehension tasks

	ALL	W	A	V	I	WV	WI	AV	AI
T_COM * V_DCO	0.08	0.04	0.51	0.03	0.77	0.26	0.07	0.08	0.47

Table 101: Results of t-tests comparing performance of the comprehension tasks

	ALL	W	A	V	I	WV	WI	AV	AI
V_DCO	1	1	1	1	1	1	1	1	2
T_COM	2	2	2	2	2	2	2	2	1

Table 102: Ranking of comprehension tasks performance between media

Table 102 shows the ranking of the PR measures of the *comprehension* task for each CS group for text and video. The coloured bands are derived from the t-tests shown in table 101.

Where there was a significant difference between the performance of subjects between the video and text *comprehension* tasks (Wholists and Verbalisers) the preference was for the video presentation. The extra information from the moving images and soundtrack appeared to improve the performance of subjects compared to a textual presentation.

7.3 Summary

This chapter presented the results of the comparisons of performance between tasks. For each CS the performance ratios achieved in each task are ranked against each other. The task rankings are different for each CS group. More differences between the performance of the CS groups are revealed by an examination of the ranking of tasks than by the ANOVA calculations presented in chapter 6. The ranking tables can be used by developers of multimedia interfaces to identify the types of task that each CS group perform well. In order to improve the performance of each CS group interfaces should be developed that contain the types of activities that are contained in the high ranked tasks and less of the activities that are contained in the low ranked tasks.

The tables in part one rank tasks performed in each media test and the tables in part two rank the different media versions of each task. Dividing tasks into bands is a refinement on the original ranking of tasks as they indicate clearly where there was a significant difference in the performance of tasks. Performance will not be significantly improved by substituting tasks from within the same coloured band.

As a general guide to improve performance of subjects the 'ALL' column should be examined to select the types of task that all 50 subjects performed well. If a subject's rating along one of the CS dimensions is known then the appropriate column, Wholist, Analytic, Verbaliser or Imager, should be examined and if the subject's rating along both CS dimensions is known then the Wholist/Verbaliser, Wholist/Imager, Analytic/Verbaliser or Analytic/Imager column should be examined in order to make a more accurate choice of task. Differences between the individual CS groups and the CS quadrants show the importance of the influence of both dimensions on the performance of subjects. Therefore the subjects CS along both dimensions should be known before making a choice of task to improve their performance. The results of the CS quadrants may give a more detailed prediction of subjects expected performance, however, these figures are based on smaller samples (roughly a quarter of the 50 subjects in each quadrant) and so may be less reliable than the figures based on the individual CSs (roughly half the subjects in each style).

To improve the performance of subjects tasks must be designed to include more of the activities that are required for the tasks in which they have achieved the highest performance. Where the performance of two types of task are not significantly differently it is not possible to recommend the activities of one task in preference to the other.

Examining the relative differences in performance of the tasks between the CS groups has identified differences that are not detected when comparing the performance of CS groups within single tasks. For example, the ANOVA calculations found no significant differences in the performance of CS groups within the tasks performed in the text/image test (table 42, chapter 6), while the t-tests (table 74 and 76) identified differences between the CS groups in the relative performance between the tasks that reflected the expected performance.

In most media tests the relative difference in performance between the tasks can be explained by the types of activities that are performed in each task as relatively simple tasks are ranked high and relatively complex tasks are ranked low. Differences in the relative performance of the CS groups were due to the inherent characteristics of each group.

There are differences in performance between the media tests which were due to the way performance was recorded, such as in the audio and video tests the time spent viewing the media is not recorded, while in the text test time spent reading the questions is recorded within the answering time.

Some of the differences between the performance of different CS groups can be explained by the expected performance of each CS group (e.g. the *comparison of concepts* task was expected to suit Verbalisers while the *comparison of objects* task was expected to suit Imagers), while others are not. An important finding of these tests was to identify in which tasks performance conformed to the expectations and in which tasks no difference in performance was found.

The instances where the performance was not as expected indicates that either the tests have revealed differences that were previously not known or that the test was not sufficiently demanding of subjects to expose the differences between the CS groups. Some of the tasks were relatively complex and performance may have been influenced by the other CS dimension rather than the dimension being examined, for example the use of high or low-imagery words in the Wholists style tasks may cause a wider range of differences in performance depending on the Verbal-Imagery classification of subjects rather than the Wholist-Analytic classification. It was difficult to predict the performance of CS groups in complex tasks that have a number of activities that may be suitable for a number of different CS groups. It was difficult to devise equivalent tasks that suited all CS groups, and to create an even spread of activities using each media that suited all CS groups. It was difficult to devise Verbaliser style tasks using images and Imager style tasks using text while it was difficult to devise purely Wholist or Analytic tasks using any media. In the case of the audio test differences were detected that supported the prior expectations when examining the relative performance of Verbalisers and Imagers within each task (see chapter 6) while an examination of the relative differences between tasks found a large number of differences some of which were opposite to the prior expectations.

The results of the experiment described in chapter 5 and presented in chapter 6 and 7 show that while there are indications that performance was as expected the majority of tasks were not performed significantly differently by either CS groups (chapter 6) or between media (chapter 7). The reasons why performance was not as expected as identified in chapter 6 includes the complexity of the tasks and the number of questions used in the test. This chapter also highlighted the influence of task complexity on performance as the simpler tasks were performed significantly better than the more complex tasks. Another experiment was needed to examine the differences in the performance of more simple activities that had less chance of containing aspects that would suit more than one dimension. The next chapter describes an experiment that compares the performance of subjects in a visual version of the CSA test with a direct equivalent audio version.

8 Comparison of the effect of Users' Cognitive Style between visual and auditory presentation of information

The aim of this chapter is to determine whether cognitive style (CS) effects the performance of users in the same manner when information is presented visually or using audio. The assessment of the relative performance of subjects using visual and auditory information was made by analysing the results of an experiment that compared the performance of subjects performing two versions of the CSA test.

A direct comparison between the performance of subjects' processing visual and auditory information that was required in order to clarify issues identified in the experiments was described in chapters 4 to 7. The results of the first set of experiments described in chapter 4 were inconclusive. CS was found to have an influence on the performance of subjects, however the tasks performed in the experiment were complex and performance was not always as expected. The combination of media used in the experiment was identified as a factor that may have influenced the performance of subjects in a previously unknown manner, therefore a second experiment was designed to examine the effect that different media exerted on the performance of subjects (described in chapter 5). As in the first set of experiments there were indications that CS influenced performance but the effects were not consistent across media and not all were as predicted. The type of activities involved in the tasks also had a strong influence on performance and there was low accuracy in predicting the relative performance of the CS groups in complex tasks. Therefore another experiment was designed to assess the relative performance of subjects between different media in simple tasks that did not contain activities that may be suitable for more than one CS group. The new test was designed using similar tasks as those used in the CSA test in order to compare performance in a visual version (using text and graphics) against the performance in an audio version (using speech and sound effects).

8.1 Design of the experiment

The main aim of performing the visual and audio experiment was to test whether there was any significant difference in performance that could be attributed to the use of different media in the presentation of information.

8.1.1 Experiment method

The experiment was designed to compare the performance of subjects between visual and auditory presentation of information. In order to ensure that there were no other factors influencing performance (which was not possible in the more complex tasks described in chapters 4 and 5) the tasks were designed to be as simple as possible. A visual version of the CSA was produced that contained tasks that were identical to the original test and an audio version was produced that replicated the tasks without using identical questions. The original CSA test was not used because the details of the performance of subjects (the score and duration for individual questions) is not available for examination after the test is complete. Subjects performed both versions of the test and their relative performance was compared. Ratios were calculated to compare the relative performance in each style of question. Performance in the Wholist style questions was compared against performance in the Analytic style questions and performance in the Wholist style questions was compared against performance in the Imager style questions. If the ratios were closely correlated between the visual and auditory versions of the test the media would not have an influence on performance, however, if the ratios were not closely correlated then this would be evidence that CS was dependent on the media used in the presentation of information.

8.1.2 Design of the visual experiment

The visual experiment used the same questions and the same interface design as the original CSA test (Riding, 1991; Riding, 1998). The position of subjects classification along each dimension was assessed by examining their relative performance (score and duration) in a series of questions that were designed to suit each CS group. It was expected that subjects would perform the questions that were designed to suit their CS relatively better than the opposite style of question i.e. Wholists were expected to perform the Wholist style questions relatively better than Analytics and Analytics were expected to perform the Analytic style questions relatively better than the Wholist style questions (Riding & Raynor, 1998; Riding & Staley, 1998). In the visual and audio experiments the CS classification of subjects is assessed by comparing their relative performance in the different styles of question. It is assumed that the relationship between the different styles within each dimension is linear and no other factors influence the calculation of style other than subjects' relative performance in each style of question.

The Verbal-Imagery classification of subjects is assessed in a series of 48 questions. Half of the questions were designed to suit Verbalisers and half were designed to suit Imagers. The questions presented statements and subjects were asked to determine whether they were *true* or *false*. The difference between the Verbaliser and Imager style questions was that the Imagers style questions used high-imagery words such as the names of objects that could be easily visualised while the Verbaliser style questions used low-imagery words. Questions that are suitable for Verbalisers used words are names of concepts such as sports, careers, food, and subjects were asked whether they were the same type, e.g.:

Figure 99: Verbaliser style question

In the statement shown in figure 99 the words *golf* and *tea pot* are not the same type but the use of the word *tea* may confuse some subjects because of the simularity with the word *tee* which is the name of an object that is used within the game of golf. Statements that are *true* contained words that are related such as *skiing* and *cricket* that were both the names of sports, while statements that are *false* contained unrelated words such as *fireplace* and *chips*. Some questions used words that were not the same type like *snooker* and *table* but may have a connection if used in a different context.

The questions that were suitable for Imagers used words that were the names of objects such as sports, careers, food, and subjects were asked whether they were the same colour, e.g.:

BREAD and BUTTER are the same COLOUR

Figure 100: Imager style question

The statement shown in figure 98 is false as *bread* is usually brown or white while *butter* is yellow. Statements that were *true* contained the names of objects that were the same colour such as *lawn* and *lettuce* that are both green. Statements that are *false* contained the names of objects that are not the same colour such as *panda* and *heather*. Some of the statements used the names of objects that are related like *teeth* and *gums* but are not the same colour.

For both Verbalisers and Imagers there were twelve statements that were *true* and twelve statements that were *false*. The order in which the *true* or *false* Verbaliser and Imager style statements were presented was distributed in a manner that could not be predicted by subjects.

The questions that assessed the classification of the Wholist-Analytic dimension used images rather than words. The questions used combinations of eleven varieties of geometric shapes ranging from simple triangles and rectangles to relatively more complex polygons, including backward L shapes and crosses. The difference between the Wholist and Analytic questions was that Wholist style questions asked subjects to identify differences in the overall appearance of objects while Analytic style questions asked subjects to identify whether simple objects were contained within more complex objects.

The questions that were suitable for Wholists presented two sets of images both comprised of three of the geometric shapes and subjects were asked whether the two images were the same e.g.:

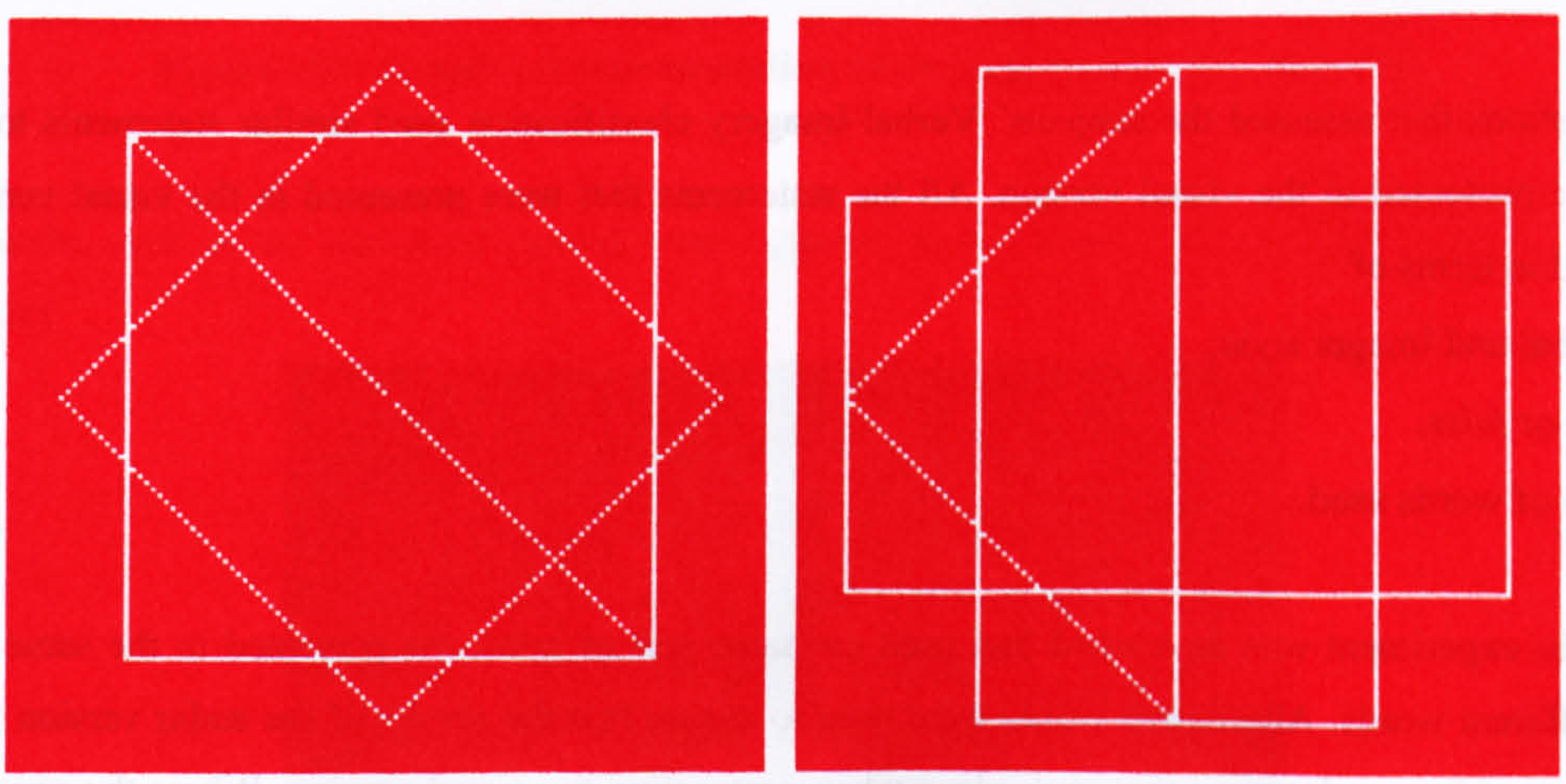


Figure 101: Wholist style question

In the example shown in figure 101 the two images are not the same. Each image is made up of three basic shapes selected from a set of eleven basic shapes used in the test.

The questions that were suitable for Analytics presented two sets of images and subjects are asked whether the first image is contained in the second e.g.:

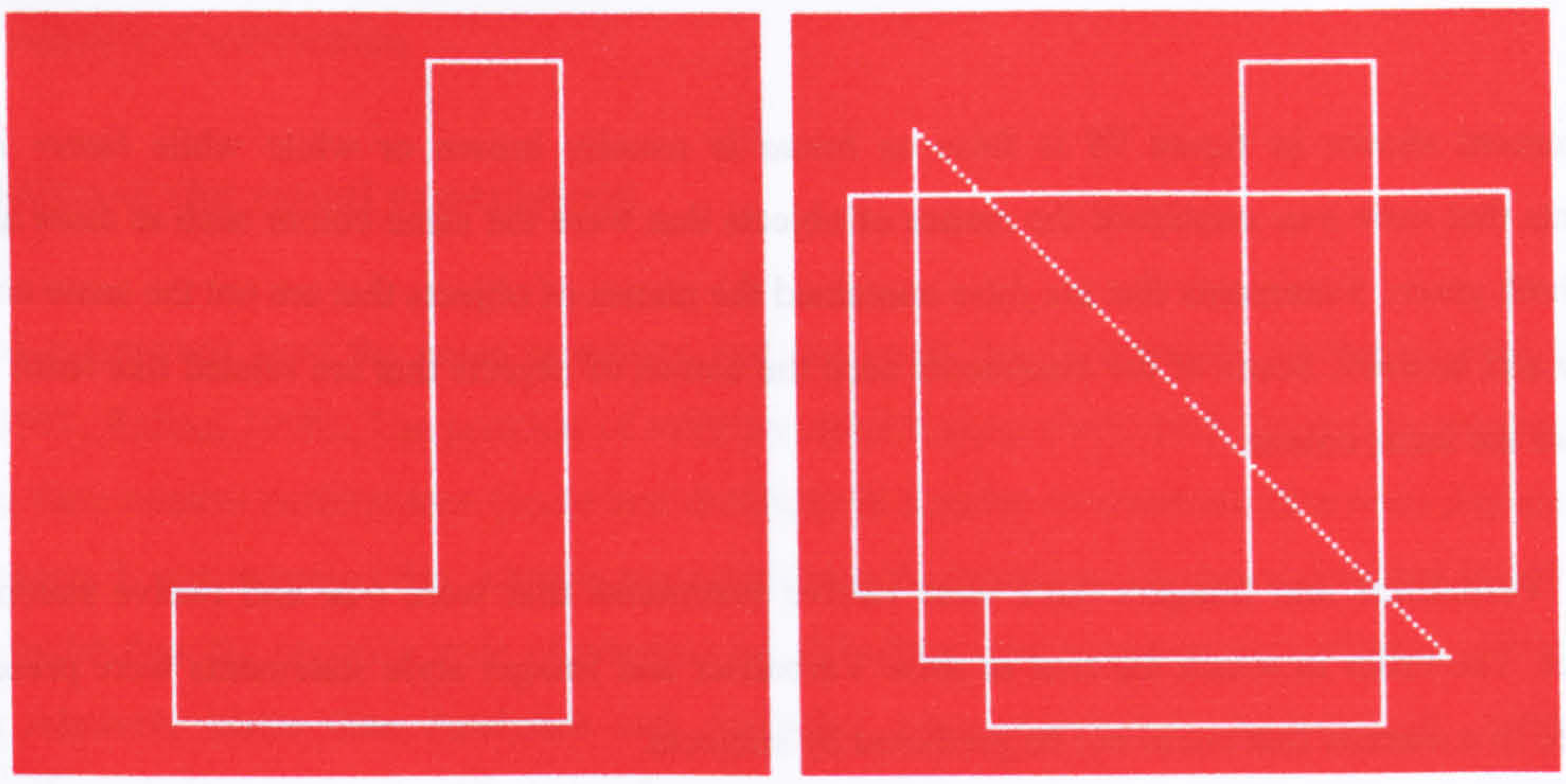


Figure 102: Analytic style question

In the question shown in figure 102 the first shape (the backward L shape) is contained within the other image which is comprised of the three basic shapes.

8.1.3 Design of the audio experiment

An audio version of the CSA test was developed that used a similar set of questions to the visual experiment. The Verbal-Imagery questions were spoken instead of displaying text and the Wholist-Analytic questions used sound effects instead of using graphics.

The questions that assessed the subjects' Verbal-Imagery classification used similar statements to the ones that were presented in the visual version. All the statements that were presented in the visual version were classified in terms of

- Verbal and Imager style,
- *true* or *false*,
- type of words used.

The audio experiment was developed that used the same sort of questions presented in the same order but using different words. Alternative words were used to ensure that the results of the audio version would not be influenced by any learning that took place when performing the visual version. Where the visual version used words that were the names of sports the audio version used the names of other sports, for example, the statement:

SKIING and CRICKET are the same TYPE

that was presented in the visual version was substituted in the audio version by the statement:

HOCKEY and RUGBY are the same TYPE.

Similarly where the visual version used words that were related in some manner but were not the same type the audio version used words that had similar meanings, for example the statement:

SNOOKER and TABLE are the same TYPE

presented in the visual version was substituted by the statement:

DARTS and BOARD are the same TYPE.

in the audio version.

The questions that assessed subjects' Wholist-Analytic classification used sound effects instead of graphics. Since the visual version used eleven basic graphical shapes the audio version used combinations of eleven basic sounds. Each graphical figure was substituted for a particular sound effect and the audio version presented the sounds in the same combinations as the visual version.

A range of sounds were chosen for their distinctiveness and variety. Each sound effect lasted exactly one second and was edited to ensure the loudest part of each sound file would be the same volume. The main difference between the sounds where the position in the file where the peak volume occurred. A number of the sound effects were louder at the start of the file than at the end (figure 103) such as the sound of a gunshot and a cannon firing.

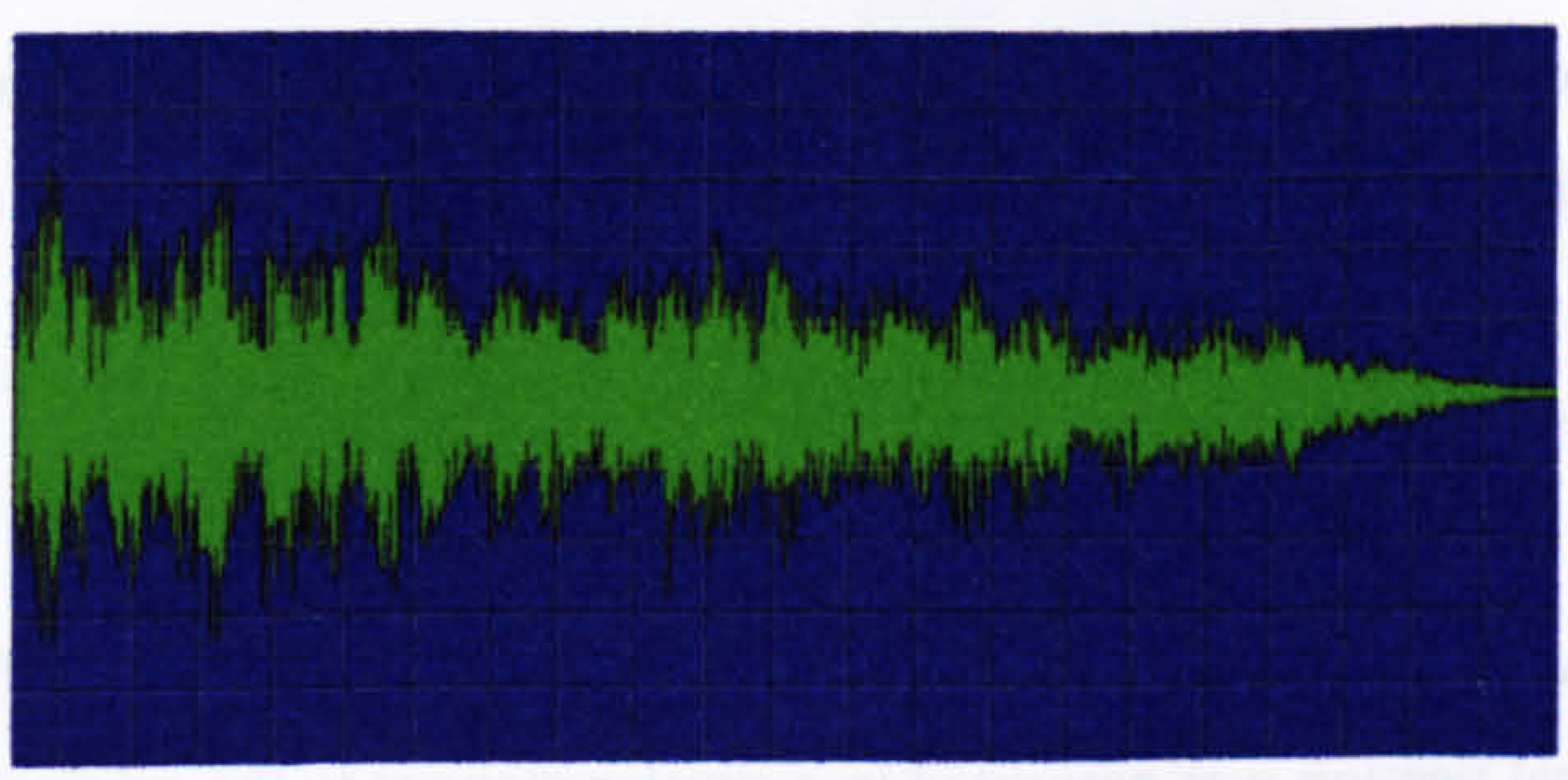


Figure 103: Graphical representation of the gun shot sound effect file

Other sounds, such as the backward cymbal were opposite to the above with the loudest peak at the end (figure 104).

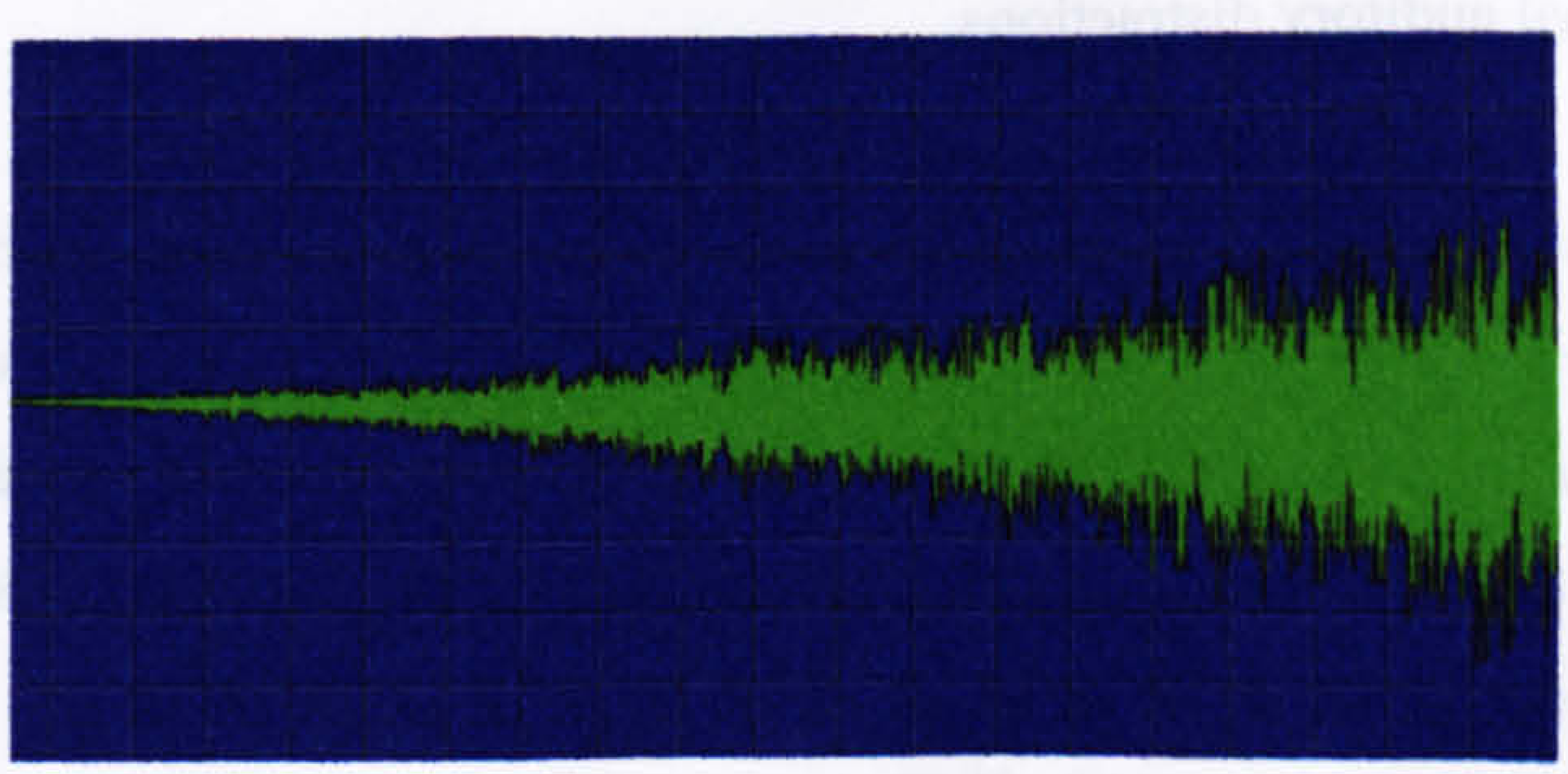


Figure 104: Graphical representation of the backward cymbal sound effect file

Other sound effects files had more than one peak, such as a switch with two peaks, and the breaking glass and turkey sounds that both had multiple peaks. Another sound effect, the buzzer, was virtually the same volume throughout.

The visual version combined three of the basic graphic figures to produce one combined figure. In the same manner the audio version combined three of the basic sound effects to produce one combined sound (figure 105). The volume of all three sounds were kept constant when the sounds were combined so all three could be heard clearly and none was swamped by the others.

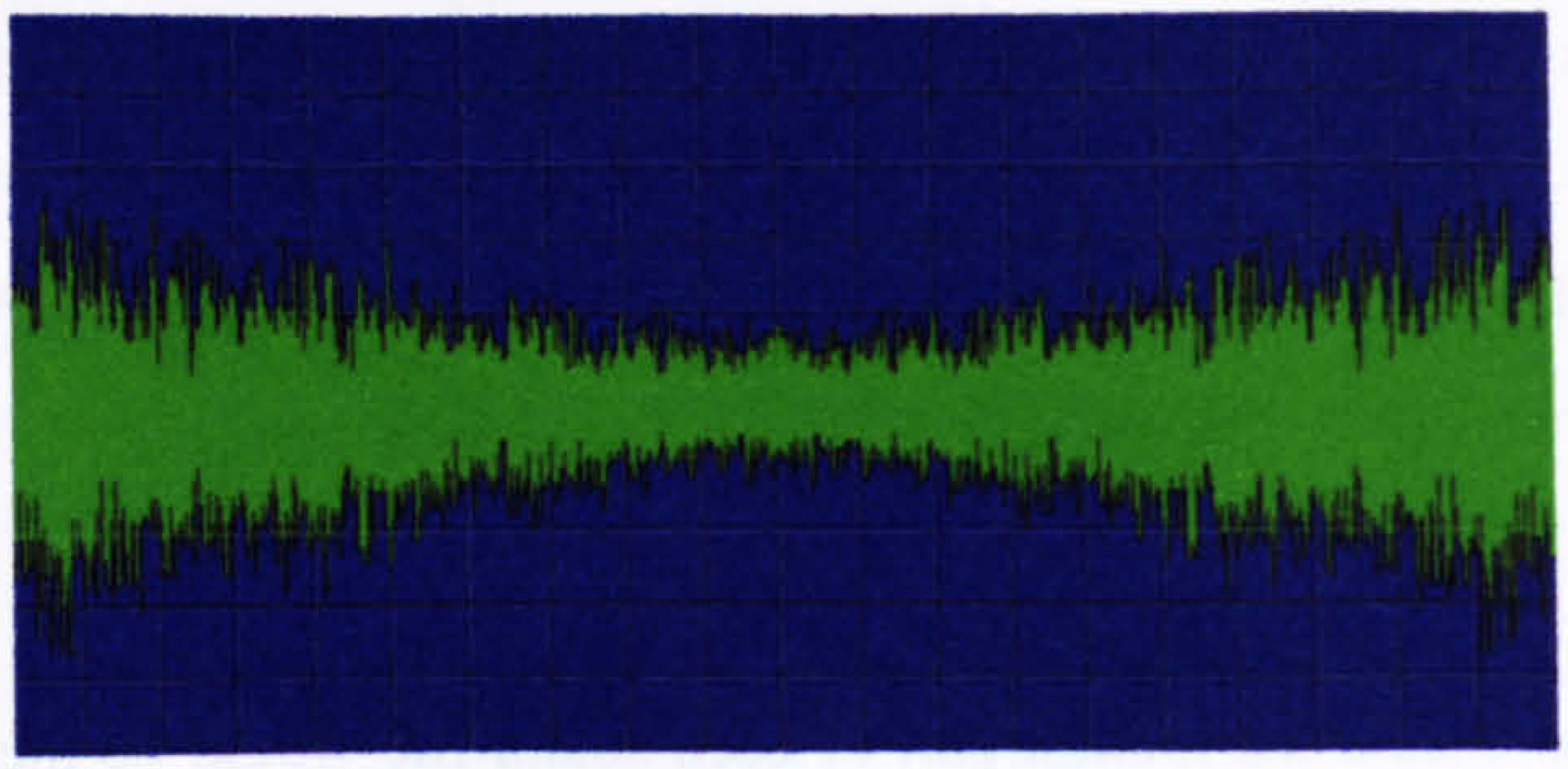


Figure 105: Graphical representation of a combined sound effect file

One difference between the visual version and the audio version was that the combination of graphical figures forms other shapes e.g. the two right angled triangles form a square, and placing one rectangle over a square forms five smaller rectangles. There was no equivalent for this feature using audio.

8.1.4 Implementation of the experiment

A computer program was implemented using VB to conduct both versions of the experiment using a multimedia PC. The visual version was presented in a similar manner to the original CSA test using the same instructions that were typed on the screen. The Verbal-Imagery questions were stored as text within a database while the graphics were stored as images taken from screen prints of the original CSA test. The audio version was conducted in the same manner except the screen was blank and subjects listened to the spoken instructions and questions. Headphones were used to ensure all subjects heard all questions clearly and there were no external auditory distractions.

Users entered their answers in the same manner as the original CSA test by pressing one of two keys on the keyboard that had either a blue or red sticker. The instructions for which key should be pressed for *true* or *false* or for *right* or *wrong* were displayed at all times in both versions of the experiment. The VB program enabled all the subjects' actions to be recorded including the time subjects spent answering each question and whether they answered correctly.

Twenty four subjects were chosen from the staff and students of Bournemouth University. Twelve of the subjects had performed the CSA test before at least twelve months previously while the other twelve had never performed the CSA test before.

On average subjects took just over five minutes to complete the visual version, while the audio version took them slightly longer as subjects had to work a the pace of the pre-recorded questions.

8.1.5 How performance was measured

The subjects performance in both versions of the test were recorded including score and duration. The duration figures recorded the whole of the time spent reading or listening to the questions and responding. It was possible for subjects to answer before the sound clip had finished playing in the same manner as it was possible to answer text questions without reading the full statements. From these basic measurements a number of measures of performance were calculated. For each style of question:

- Score was calculated as the percentage of questions answered correctly.

$$Score = \left(\frac{Total\ Correct\ Answers}{Total\ Number\ of\ Questions}\right) X100$$

- Mean Duration was calculated as the total duration divided by the number of questions.

$$Mean\ Duration = \left(\frac{Total\ Duration}{Total\ Number\ of\ Questions}\right)$$

- Median Duration was calculated as the median duration figures of all individual questions.
- Performance ratio using the average duration.

$$Mean\ Performance\ Ratio = \left(\frac{Score\%}{Mean\ Duration}\right)$$

- Performance ratio using the median duration.

$$Median\ Performanc\ e\ Ratio = \left(\frac{Score\%}{Median\ Duration}\right)$$

The CSA ratios indicate a person's relative ability to answer one style of questions compared to the opposite style of questions. An individual's position along either dimension is represented as a value between 0 and 2. Therefore a similar range of values were produced to compare the relative performance of subjects between both halves of each dimension. The CSA Verbal-Imagery ratio indicates a Verbaliser classification where the ratio is in the lower range and an Imager classification where the ratio is in the higher range (Riding, 1991; Riding, 1998; Riding & Rayner, 1998; Riding & Staley, 1998). It is possible to create a similar ratio by calculating the subjects' performance in the Imager style questions as a percentage of the overall performance (performance in the Verbaliser style questions added to the performance in the Imager style questions). For each measure of performance in the visual and audio experiments a ratio was produced showing the performance in Imagers style questions as a percentage of the total performance in the Verbalisers and Imagers style questions. Figures of less than 1.00 indicate that the Verbaliser style questions were performed better than the Imager style questions, while figures of more than 1.00 indicate that the Imager style questions were performed better than the Verbaliser style questions.

- Verbal-Imagery Score ratio:

$$Verbal - Imagery\ Score\ Ratio = \left(\frac{Imager\ Score\ \%}{Verbaliser\ Score\ \% + Imager\ Score\ \%}\right) X2$$

- Verbal-Imagery Mean Duration ratio:

$$Verbal - Imagery\ Mean\ Dration\ Ratio = \left(\frac{Imager\ Mean\ Duration}{Verbaliser\ Mean\ Duration + Imager\ Mean\ Duration}\right) X2$$

- Verbal-Imagery Median Duration ratio:

$$Verbal - Imagery\ Median\ Dration\ Ratio = \left(\frac{Imager\ Median\ Duration}{Verbaliser\ Median\ Duration + Imager\ Median\ Duration}\right) X2$$

- Verbal-Imagery Mean Performance Ratio:

$$Verbal - Imagery\ Mean\ PR = \left(\frac{Imager\ Mean\ PR}{Verbaliser\ Mean\ PR + Imager\ Mean\ PR}\right) X2$$

- Verbal-Imagery Median Performance Ratio:

$$Verbal - Imagery\ Median\ PR = \left(\frac{Imager\ Median\ PR}{Verbaliser\ Median\ PR + Imager\ Median\ PR}\right) X2$$

The CSA Wholist-Analytic ratio is created in a similar manner as the Verbal-Imagery ratio. Similar ratios were created by calculating the subject's performance in the Analytic style questions as a percentage of the overall performance. For each measure of performance in the visual and audio experiments a ratio was produced showing the performance in the Analytic style questions as a percentage of the total performance in the Wholist and Analytic style questions. Figures of less than 1.00 indicate that the Wholist style questions were performed better than the Analytic style questions, while figures of more than 1.00 indicate that the Analytic style questions were performed better than the Wholist style questions.

A number of different performance measures were compared with the original CSA test ratios. This comparison was made to help identify which measure of performance most closely matches the original CSA classification. The mean was considered as it takes into account the whole of the duration. Also the median duration per question was considered as this figure removes any abnormal distortions which may have occurred while subjects were learning how to answer the questions or lost concentration.

8.2 Results of the visual and audio experiments

The results of the experiments are presented in three ways:

1. The performance of the eleven subjects who performed the original version of the CSA in the visual and audio experiments is compared with their original CSA test ratios.
2. The performance of subjects is compared between each style of question. The performance of subjects in the Verbaliser style questions are compared with their performance in the Imager style questions and the performance of subjects in the Wholist style questions are compared with their performance in the Analytic style questions.
3. The performance of subjects in the visual version was compared with their performance in the audio version.

Comparisons were made by performing correlation calculations i.e. testing whether subjects who performed relatively better at one style of question in one test also performed relatively better at the same style of questions in the other test.

8.2.1 Comparison between the visual and audio experiments and the original CSA test

The comparison between the performance in the visual and audio tests with the original CSA ratios was made in order to help identify which measures of performance are most closely correlated with the original CSA classification and to test the performance was affected by media.

Twelve of the subjects who performed the visual and audio experiments had also performed the original CSA test. In order to prevent the performance in the visual experiment being affected by prior knowledge gained by recently performing the original test. Subjects were chosen who had not performed the CSA test for at least twelve months. The ratios achieved by these subjects in the original CSA test were compared with the ratios produced from the performance in the visual and audio experiment.

The ratios of the Wholist-Analytic dimension and the Verbal-Imagery dimension that were produced by the CSA test give figures that are usually between 0.00 and 2.00. Higher figures are possible but rare (Riding, 1991; Riding, 1998). The formula used by the CSA test is a commercial secret and are not reproduced exactly. The calculation also includes a weighting for sex and age but it is assumed that these attributes will not significantly effect the overall classification (Riding et al., 1995; Riding & Rayner, 1998). The CSA literature stresses the importance of the relative duration figures in assessing CS (Riding, 1991; Riding, 1998; Riding & Rayner, 1998; Riding & Staley, 1998). It is assumed that the ratios produced by the original CSA test are calculated by assessing the relative performance in a linear manner and that the performance figures of one style of question are not adjusted without a corresponding adjustment on the performance figures of the opposite style of question.

It was expected that subjects who were assessed as Wholists by the CSA test would perform the Wholist style questions in the visual and audio experiments relatively better than the Analytic style questions and vice versa. Similarly it was expected that subjects that were assessed as Verbalisers by the CSA test would perform the Verbaliser style questions relatively better than the Imager style questions and vice versa. This assumption is tested using a correlation calculation. High ratios in the original CSA test were expected to be matched by high ratios in the visual and audio experiments and low ratios in the original CSA test were expected to be matched by low ratios in the visual and audio experiments.

The correlation coefficient measures relationship between two properties indicating whether the value of one property depends on the value of the other property. The result of the calculation is a figure between - 1 and + 1. The closer the figure is to 1 the stronger the relationship between the two values. The critical value that indicates a significant relationship varies depending on the degrees of freedom (the number of observations minus two). For twelve subjects there are 10 degrees of freedom and the critical value for a significant correlation ($p = 0.05$) is 0.576 and above and for a marginally significant correlation ($p = 0.10$) is between 0.498 and 0.576 (Howell, 1995).

	Correlation		Correlation
CSA WA * Vs_WA_AD	-0.178	CSA WA * Au_WA_AD	-0.034
CSA WA * Vs_WA_MD	-0.692	CSA WA * Au_WA_MD	0.010
CSA WA * Vs_WA_S	-0.146	CSA WA * Au_WA_S	-0.026
CSA WA * Vs_WA_AP	0.117	CSA WA * Au_WA_AP	-0.011
CSA WA * Vs_WA_MP	0.603	CSA WA * Au_WA_MP	-0.038
CSA VI * Vs_VI_AD	-0.036	CSA VI * Au_VI_AD	0.541
CSA VI * Vs_VI_MD	0.164	CSA VI * Au_VI_MD	0.356
CSA VI * Vs_VI_S	-0.197	CSA VI * Au_VI_S	-0.487
CSA VI * Vs_VI_AP	-0.081	CSA VI * Au_VI_AP	0.532
CSA VI * Vs_VI_MP	-0.217	CSA VI * Au_VI_MP	-0.499

Table 103: Correlation between performance in the visual and audio experiments with the CSA test ratios

Table 103 shows the results of the comparisons between the performance measures achieved in the visual and audio experiments with the ratios calculated by the CSA test. The Wholist-Analytic ratio (CSA WA) and the Verbal-Imagery ratio (CSA VI) calculated by the original CSA test are compared against the performance measures calculated in the visual experiment (Vs_) in the first set of columns and the audio test (Au_) in second set of columns. The measures of performance include the average duration (_AD), the median duration (_MD), score (_S), the PR calculated with the average duration (_AP) and the PR calculated with the median duration (_MP). The measures of performance that were significantly correlated are highlighted with a yellow background and the measures that were marginally significantly correlated are highlighted with a green background.

As expected table 103 shows that duration was more strongly correlated to the CSA ratios than score but there were differences between the different styles of question and between different media experiments. For the Wholist-Analytic questions in the visual experiment the measure of performance that was most closely correlated to the CSA Wholist-Analytic ratio was the PR calculated using median duration (CSA WA * Vs_WA_MP, correlation=0.603). The distribution of subjects' performance for this calculation is illustrated by figure 106.

Figure 106 shows the correlation between the PRs calculated using score divided by the marginal duration figure of the Wholist-Analytic tasks in the visual experiment (Vs_WA_MP) with the Wholist-Analytic ratios calculated by the original CSA test (CSA_WA). High Wholist-Analytic ratios in the CSA test are matched by high marginal duration Wholist-Analytic ratios in the visual experiment. This correlation was within the significant level which indicates that the PR calculated using the median duration for the Wholist-Analytic tasks in the visual experiment can be used to indicate the CSA test classification of the Wholist-Analytic ratio.

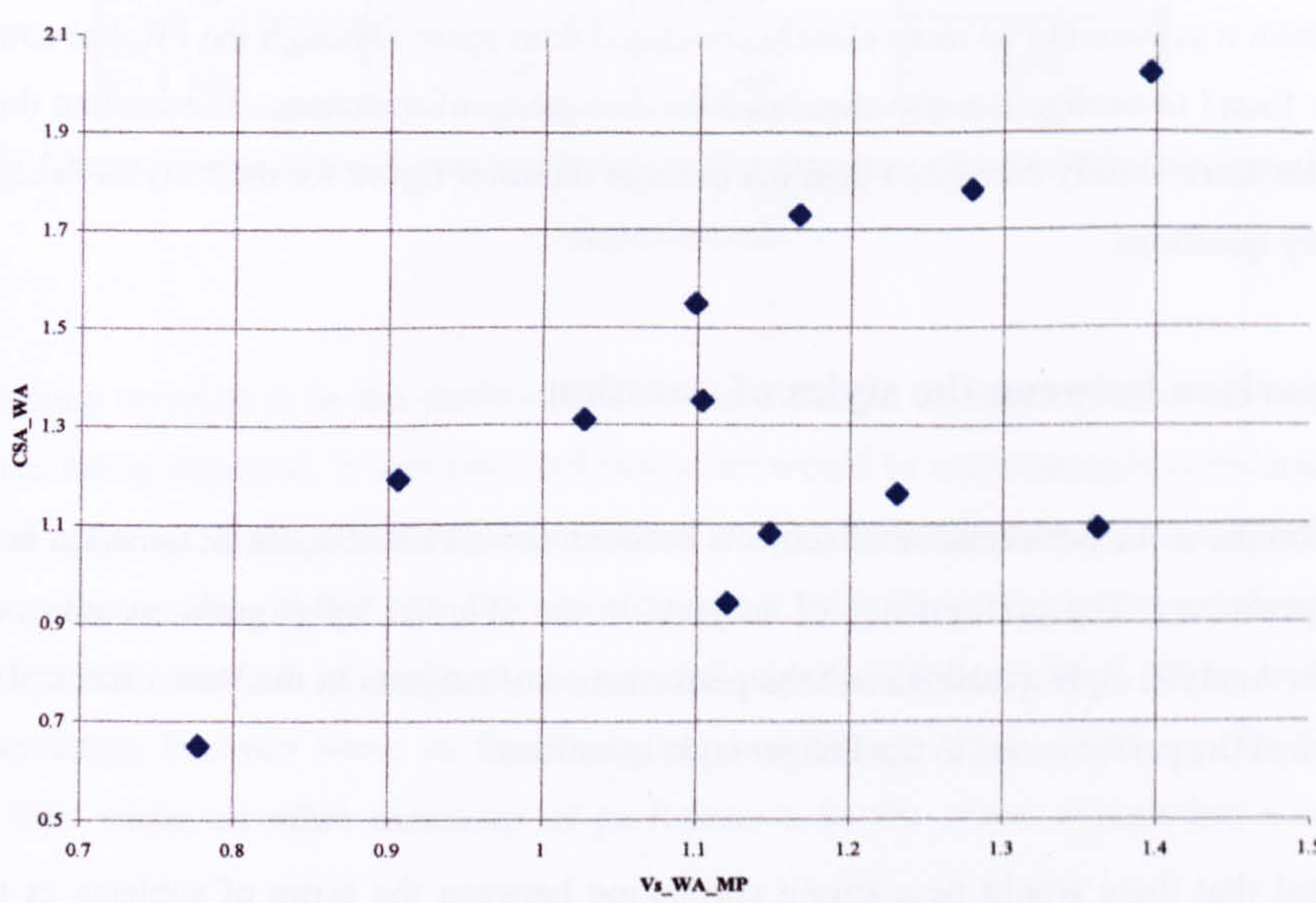


Figure 106: CSA WA * Vs_WA_MP scatter graph

In the audio experiment the CSA Wholist-Analytic ratio was also most closely correlated to the PR that was calculated using median duration (CSA WA * Au_WA_MP, correlation=0.010). This correlation was below the significant level but most closely correlated as all other correlation figures were negative. This result shows there were differences in the relative performance of Wholist-Analytic questions which depends on whether presentation is visual or audio.

For the Verbal-Imagery dimension the CSA Verbal-Imagery ratio was most closely correlated with the median duration (CSA VI * Vs_VI_MD, correlation=0.164). This correlation was below the significant level while all other correlation figures were negative. In the audio experiment the measure of performance that was most closely correlated to the CSA Verbal-Imagery ratio was average duration (CSA VI * Au_VI_AD, correlation=0.541). This correlation was within the marginally significant level. The result indicates that there was a difference in the relative performance of Verbal-Imagery questions dependent on whether the presentation was visual or uses audio.

Differences in the perception of visual and audio information were indicated as the pattern of correlation between the CSA ratios and the measures of performance were different for both versions. While there was a strong correlation between the median duration measures for the Wholist-Analytic style questions in the visual experiment there were no significant correlation matches for the audio experiment. In contrast, while were there no significant correlation matches between the Verbal-Imagery measures of performance in the visual experiment, there were marginally significant correlation matches in the audio experiment.

The pattern of correlation between the measures of performance and the CSA ratios were not the same between the different styles of questions and between the visual and audio experiments and so it was not possible to positively identify the most important measure of performance that determines CS. However, as expected duration was found to be more closely correlated than score although the PR that combines duration and score was found to be significantly correlated for one group of questions. The median duration measure was found to be more closely correlated than the average duration figure for most styles except for the audio Verbal-Imagery questions.

8.2.2 Comparison between the styles of question

This section compares the performance of subjects between the different styles of question in both the visual and audio experiments. The performance of subjects in the Wholist style questions was compared to the performance in Analytic style questions and the performance of subjects in the Verbaliser style questions was compared against the performance in the Imager style questions.

It was expected that there would be a strong correlation between the score of subjects as this reflects the subjects' ability. Subjects who scored high at one style of question were expected to score high at the other style of question and subjects who scored low at one style were expected to score low at the other. In contrast it was expected that there would be differences in duration between the styles of question by the CS groups (Riding, 1998; Riding & Rayner, 1998; Riding & Staley, 1998).

Table 104 shows the correlation between the CSA ratios and the performance measures (_AD, _MD, _S, _AP and _MP) achieved for each style of question (W, A, V and I) within the visual (Vs_) and audio (Au_) experiments. For both experiments the performance in the Wholist style questions (W) is compared against Analytic style questions (A) and the performance in the Verbaliser style questions (V) is compared against the Imager style questions (I). The yellow backgrounds indicate a significant correlation and the green backgrounds indicate a marginally significant correlation. For twenty four subjects there are 22 degrees of freedom and so the critical value for a significant correlation relationship (p=0.050) is plus or minus 0.404 and above and the critical value for a marginally significant correlation relationship (p=0.100) is between plus or minus 0.344 and 0.404 (Howell, 1995).

	Correlation		Correlation
Vs_W_AD * Vs_A_AD	0.690	Au_W_AD * Au_A_AD	0.774
Vs_W_MD * Vs_A_MD	0.451	Au_W_MD * Au_A_MD	0.688
Vs_W_S * Vs_A_S	-0.190	Au_W_S * Au_A_S	0.391
Vs_W_AP * Vs_A_AP	0.751	Au_W_AP * Au_A_AP	0.484
Vs_W_MP * Vs_A_MP	0.619	Au_W_MP * Au_A_MP	0.443
Vs_V_AD * Vs_I_AD	0.897	Au_V_AD * Au_I_AD	0.710
Vs_V_MD * Vs_I_MD	0.918	Au_V_MD * Au_I_MD	0.713
Vs_V_S * Vs_I_S	0.389	Au_V_S * Au_I_S	0.485
Vs_V_AP * Vs_I_AP	0.901	Au_V_AP * Au_I_AP	0.627
Vs_V_MP – Vs_I_MP	0.919	Au_V_MP * Au_I_MP	0.606

Table 104: Comparisons of performance between the question styles within the visual and audio experiments

There was a strong correlation in the performance of the different styles of question however the relative differences were not as expected. It was expected that score would be more strongly correlated than duration but the opposite occurred. In the visual experiment there was no correlation between score in the Wholist and Analytic style questions (Vs_W_S * Vs_A_S, correlation=-0.190). These figures were below the significant level, while all other measures of performance were all significantly correlated. There was a marginally significant correlation between score in the Verbaliser and Imager style questions (Vs_V_S * Vs_I_S, correlation=0.389) while all other measures of performance in the visual experiment were significantly correlated.

In the audio experiment there was a marginally significant correlation between the score in the Wholist and Analytic style questions (Au_W_S * Au_A_S, correlation=0.391) while all other measures of performance in the visual experiment were significantly correlated. There was a significant correlation between score in the Verbaliser and Imager style questions (Au_V_S * Au_I_S, correlation=0.485) but this was the lowest correlation figure for all the Verbal-Imagery measures of performance in the audio experiment.

The results of the correlation calculations between the different styles of question were opposite to expected as more difference between the styles of question were shown up by the score figures rather than duration.

8.2.3 Comparison between the media experiments

This section compares the performance of subjects between the visual and audio experiments. The performance of subjects in all styles of question within the visual experiment were compared against the corresponding measures of performance in the audio experiment. Both experiments used equivalent questions so any difference in performance that occurred between the two experiments was due to the media used in the presentation.

Table 105 shows the correlation between the performance measures (_AD, _MD, _S, _AP and _MP) achieved in the visual experiment (Vs_) with the audio experiment (Au_). The performance of subjects in each style of question (W, A, V and I) and the ratios derived for each dimension (WA and VI) in both experiments are compared against each other. The levels of significance were the same as for table 104.

	Correlation		Correlation
Vs_W_AD * Au_W_AD	0.259	Vs_V_AD * Au_V_AD	0.245
Vs_W_MD * Au_W_MD	0.145	Vs_V_MD * Au_V_MD	0.209
Vs_W_S * Au_W_S	-0.183	Vs_V_S * Au_V_S	0.542
Vs_W_AP * Au_W_AP	0.424	Vs_V_AP * Au_V_AP	0.340
Vs_W_MP * Au_W_MP	0.395	Vs_V_MP * Au_V_MP	0.313
Vs_A_AD * Au_A_AD	0.701	Vs_I_AD * Au_I_AD	0.530
Vs_A_MD * Au_A_MD	0.604	Vs_I_MD * Au_I_MD	0.508
Vs_A_S * Au_A_S	0.229	Vs_I_S * Au_I_S	0.288
Vs_A_AP * Au_A_AP	0.591	Vs_I_AP * Au_I_AP	0.534
Vs_A_MP * Au_A_MP	0.531	Vs_I_MP * Au_I_MP	0.465
Vs_WA_AD * Au_WA_AD	-0.180	Vs_VI_AD * Au_VI_AD	0.209
Vs_WA_MD * Au_WA_MD	-0.257	Vs_VI_MD * Au_VI_MD	0.165
Vs_WA_S * Au_WA_S	0.006	Vs_VI_S * Au_VI_S	0.453
Vs_WA_AP * Au_WA_AP	-0.014	Vs_VI_AP * Au_VI_AP	0.327
Vs_WA_MP * Au_WA_MP	-0.085	Vs_VI_MP * Au_VI_MP	0.324

Table 105: Comparisons of performance between the visual and audio experiments

The correlation figures reveal more differences between the performance of the different styles of questions in the visual and audio experiments. The performance of the Verbaliser questions produced the opposite correlation results than the Imager questions. The performance of the Verbaliser score figures were significantly correlated between the visual and audio experiments (Vs_V_S * Au_V_S, correlation=0.542) while none of the other measures were significantly correlated. The performance of the Imager score figures were not significantly correlated between the visual and audio experiments (Vs_I_S * Au_I_S, correlation=0.288) while all of the other measures of performance were significantly correlated. The correlation of the Analytic questions between the visual and audio experiments produced similar results to the Imager questions. The duration and score measures in Wholists questions were not significantly correlated between the visual and audio experiments but the PRs using the average duration were significantly correlated (Vs_W_AP * Au_W_AP, correlation=0.424) and there was a marginally significant correlation between PRs using the median duration (Vs_W_MP * Au_W_MP, correlation=0.395).

It was important to compare the PRs between the Wholist-Analytic style questions and between the Verbal-Imagery style questions as these give an overall indication of relative performance. Unlike the comparison of individual question styles there were closer correlation between the performance of score than duration. For the Wholist-Analytic questions the performance of score was most closely correlated between the visual and audio experiments (Vs_WA_S * Au_WA_S, correlation=0.006). This was not a significant correlation but all other measures produced negative correlation figures.

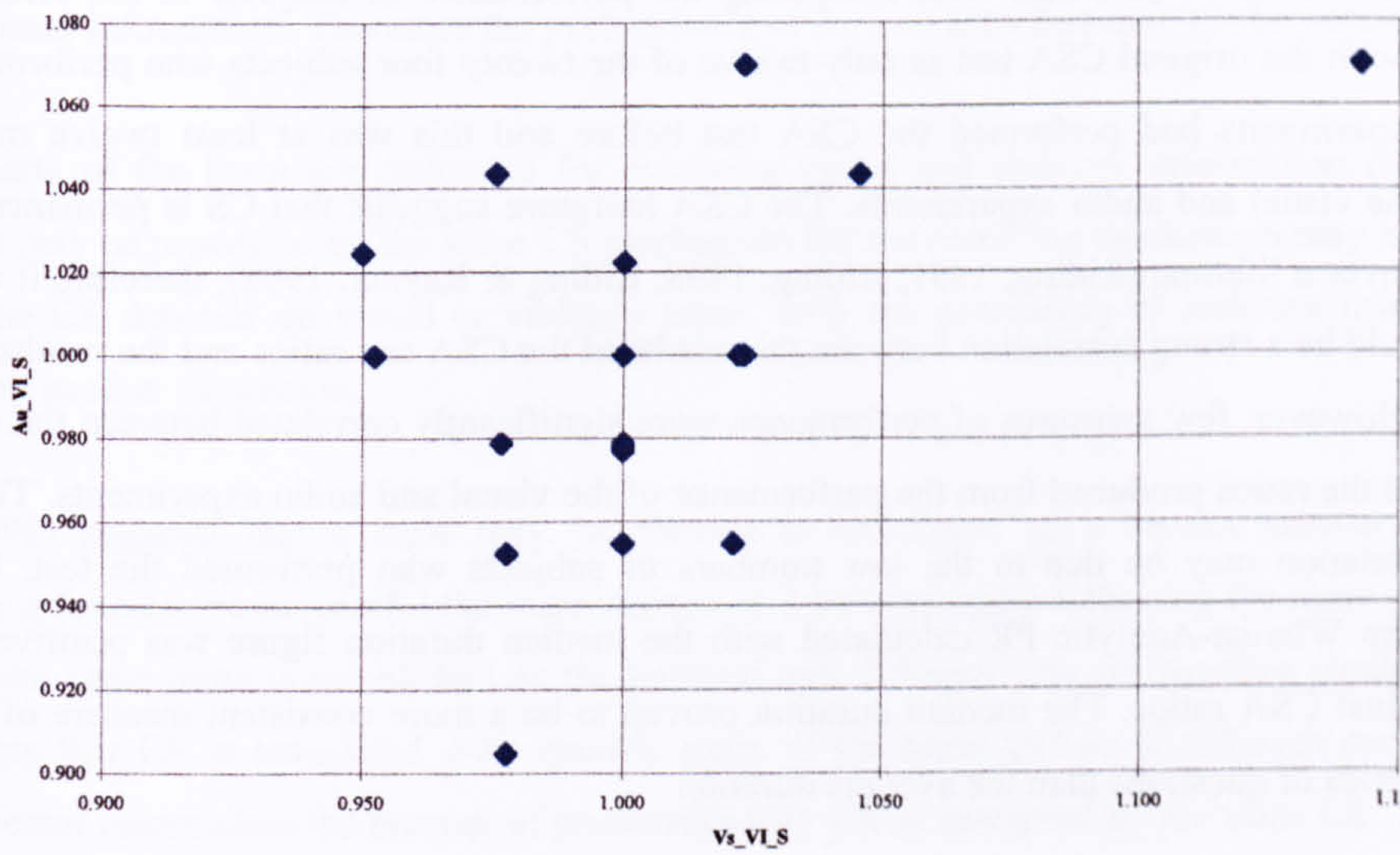


Figure 107: Vs_VI_S * Au_VI_S scatter graph

For the Verbal-Imagery dimension was only significantly correlated measure of performance between the visual and audio experiment was score (Vs_VI_S * Au_VI_S, correlation=0.453). This result is illustrated by figure 107.

Figure 107 shows the correlation between the score ratios in the visual experiment (Vs_VI_S) and the audio experiment (Au_VI_S). High Verbaliser-Imager score ratios in the visual experiment are matched by high Verbaliser-Imager score ratios in the audio experiment. This result indicates that the performance for score in the Verbal-Imagery questions is the same whether the presentation is visual or uses audio, however all the other measures of performance for the Verbal-Imagery dimension ratios and the Wholist-Analytic dimension ratios indicate that performance is dependent on the media used.

8.3 Discussion

This section discusses a number of issues connected with the performance in the visual and audio experiments and the implications they have on the classification of CS. These issues include:

- The identification of the performance measure that has most influence on the calculation of the CS dimensions,
- whether the audio Wholist-Analytic task was equivalent to the visual task, and
- what evidence is there that performance is dependent on the visual or audio presentation of information.

In order to identify the measure of performance that most closely matches the CSA ratios the performance measures derived from the visual and audio experiments were compared against the ratios calculated by the CSA test.

There were a number of problems with comparing the performance of subjects in the visual and audio experiments with the original CSA test as only twelve of the twenty four subjects who performed the visual and audio experiments had performed the CSA test before and this was at least twelve months before performing the visual and audio experiments. The CSA literature suggests that CS is permanent and would change little over a lifetime (Riding, 1991; Riding, 1998; Riding & Rayner, 1998), therefore it was expected that there would be a strong correlation between the results of the CSA test ratios and the results of the visual experiment. However, few measures of performance were significantly correlated between the original CSA test ratios and the ratios produced from the performance of the visual and audio experiments. The absence of a strong correlation may be due to the low numbers of subjects who performed the test. In the visual experiment the Wholist-Analytic PR calculated with the median duration figure was positively correlated with the original CSA ratios. The median duration proved to be a more consistent measure of performance over a long series of questions than the average duration.

There could be a number of reasons why there were few measures of performance that were significantly correlated with the CSA ratios. One difference may be the formulas used in producing the ratios. The formula used by the CSA test is a commercial secret and it is not known what weightings are placed on each measurement.

The comparison of the audio experiment with the original CSA ratios showed no significant correlation with the Wholist-Analytic questions but showed a marginal correlation with the Verbal-Imagery questions. This would suggest that the performance in the Verbal-Imagery questions would be similar whether the information was presented using visual or audio information while performance of the Wholist-Analytic questions would depend on media that was used to present the information.

There is a lot of evidence that subjects performed differently depending on whether information was presented visually or using audio. Differences were shown up by the degree of correlation between the CSA ratios and the visual and audio experiments by comparing the different styles of question within each experiment and comparing performance between the visual and audio experiments (tables 115 to 117).

The differences in performance between the visual and audio experiments reflect the differences in the human sensory system receiving the visual and audio information. The only difference between the questions used for the two dimensions is on the usage of language. Both the visual and audio experiments used written or spoken language in the Verbal-Imagery questions. The audio and visual signals are received in different parts of the brain, but are processed in the part of the brain that deals with language. Therefore any difference in performance between the visual and audio versions could be attributed to differences in the sensory system used rather than brain language processing differences.

The visual and audio versions of the Wholist-Analytic questions were more fundamentally different than the Verbal-Imagery questions as the processing of the visual and audio non-language information may not occur in the same part of the brain. Identifying sound effects may take place in the areas of the brain associated with receiving audio information while recognising shapes takes place in the part of the brain associated with receiving visual information. Therefore the performance of the two activities may not be connected.

Different parts of the brain are dedicated for receiving visual and auditory information (chapter 5). The information may be processed by the same CS mechanism but the receiving mechanism may have more of an effect, or the CS depends on visual or auditory input, with the processing of auditory information being controlled by another dimension.

Riding (1998) suggests that a style may be formed in childhood as a certain manner of processing information is found to be successful the same manner will be tried again following the same pathways in the brain until the same route is established as the habitual and different way of handling similar information. This suggests that CS is associated with specific parts of the brain and so if different parts of the brain process different information the manner of processing may not be governed by the same CS. The test results may differ depending on whether they were audio or visual. Language is expected to be handled by the same part of the brain whether the information is input visually or using audio, while non-speech sounds and images are handled in different parts of the brain (see chapter 5). Therefore it may be expected that the processing of the Verbal-Imagery questions will be the same whether information is presented visually or using audio, while the Wholist-Analytic questions would show a wider variation between the visual and audio experiments. There were more indications of a correlation between the performance of the Verbal-Imagery style questions than the Wholist-Analytic style questions in the visual and audio tests (table 105). However the correlation between the Verbal-Imagery and Wholist-Analytic ratios were low.

The difference in performance between the visual and audio experiments mean that visual tests such as the CSA test do not give a complete assessment of CS. A person's CS appears to be more complex and a more complete description should take into account a Wholist-Analytic and Verbal-Imagery classification for visual information and a Wholist-Analytic and Verbal-Imagery classification for audio information.

Figure 108 shows the addition of the audio dimension to the CS model. A person's CS is calculated by performing a visual version of the CSA test augmented with an audio version. The first test produces a Visual-Wholist-Analytic ratio and a Visual-Verbal-Imagery dimension (the top plane in figure 108) and the second test produces a Audio-Wholist-Analytic ratio and an Audio-Verbal-Imagery ratio (the bottom plane in figure 108).

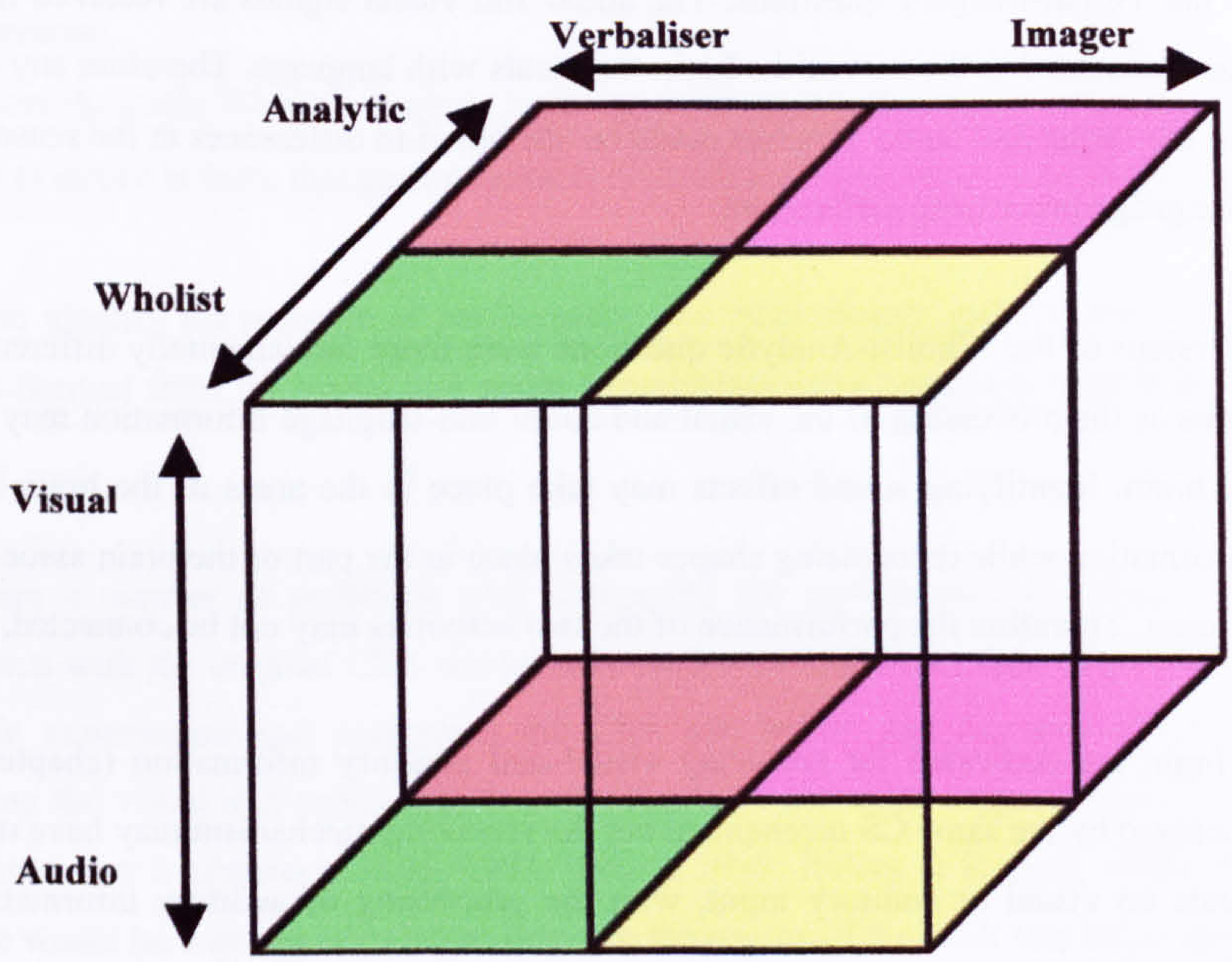


Figure 108: Adding a visual and audio dimension to the cognitive style model

An assessment of an individuals' visual-audio dimension can be made for both dimensions by comparing the performance in the visual and audio experiments. For the Wholist-Analytic dimension the performance of all subjects can be assessed by creating a PR of all Wholist-Analytic questions in the visual experiment and another PR for the audio experiment. The relative performance between the visual and audio experiments can be assigned a ratio as follows:

$$VisualAudio\ PR = \left(\frac{Visual\ PR}{Audio\ PR + Visual\ PR}\right) X\,2$$

The resulting figure indicates the relative performance of the subject between the visual experiment and the audio experiment. The figure would be within the range of 0.00 to 2.00, with a figure of more than 1.00 indicating that the subject performed the visual experiment better than in the audio experiment and a figure of less than 1.00 indicating that the subject performed the audio experiment better than in the visual experiment. A visual-audio ratio can be calculated for both the Wholist-Analytic and the Verbal-Imagery dimensions.

Visual-audio ratios were calculated for all subjects who performed the experiments, and the degree of correlation between the two sets of ratios were calculated. The degree to which the visual-audio ratios of the Wholist-Analytic and the Verbal-Imagery dimensions are correlated indicates whether there is one visual-audio dimension or each dimension interacts with the visual-audio dimension independently. If the ratios were strongly correlated it would show both dimensions interacted with the presentation style in the same manner while a weaker correlation would support the conclusion that the performance of Wholist-Analytic and Verbal-Imagery style questions were effected by the visual-audio style of presentation in an independent manner.

Figure 109 shows a scatter graph of the subjects Wholist-Analytic visual-audio PR calculated using the median duration (VsAu_WA) compared to their Verbal-Imagery visual-audio PR calculated using the median duration (VsAu_VI). The general trend is that high Wholist-Analytic dimension ratios matched by high Verbal-Imagery dimension ratios and vice versa. This is not unexpected as subjects who performed well in one style of question with one style of presentation for one style of question are likely to perform well in all styles of question with the same style of presentation, however, there are a number of exceptions. The correlation between the two dimensions was only marginally significant (VsAu_WA * VsAu_VI, correlation=0.352) which indicates that while most of the relative differences can be explained by the ability of subjects to perform visual or audio tasks there was another influence on performance. The other influence may be the effect of CS interacting with presentation style. As the visual and audio questions are expected to be equivalent for each style of question any difference in performance can be attributable to the effect of the visual or audio style of presentation. For each dimension the effect of the visual or audio style of presentation is reflected in the visual-audio ratio and any variation due to CS (one style of questions being performed relatively better or worse than other style of questions in one presentation style and not in the other presentation style) is reflected in the comparison of PRs between the two dimensions. The overall effect of CS on the correlation is weakened if the effect that presentation style has on one style of questions is matched by a similar effect on the other style of question in the other presentation style, or the overall effect on one dimension is independently matched by a similar effect on the other dimension.

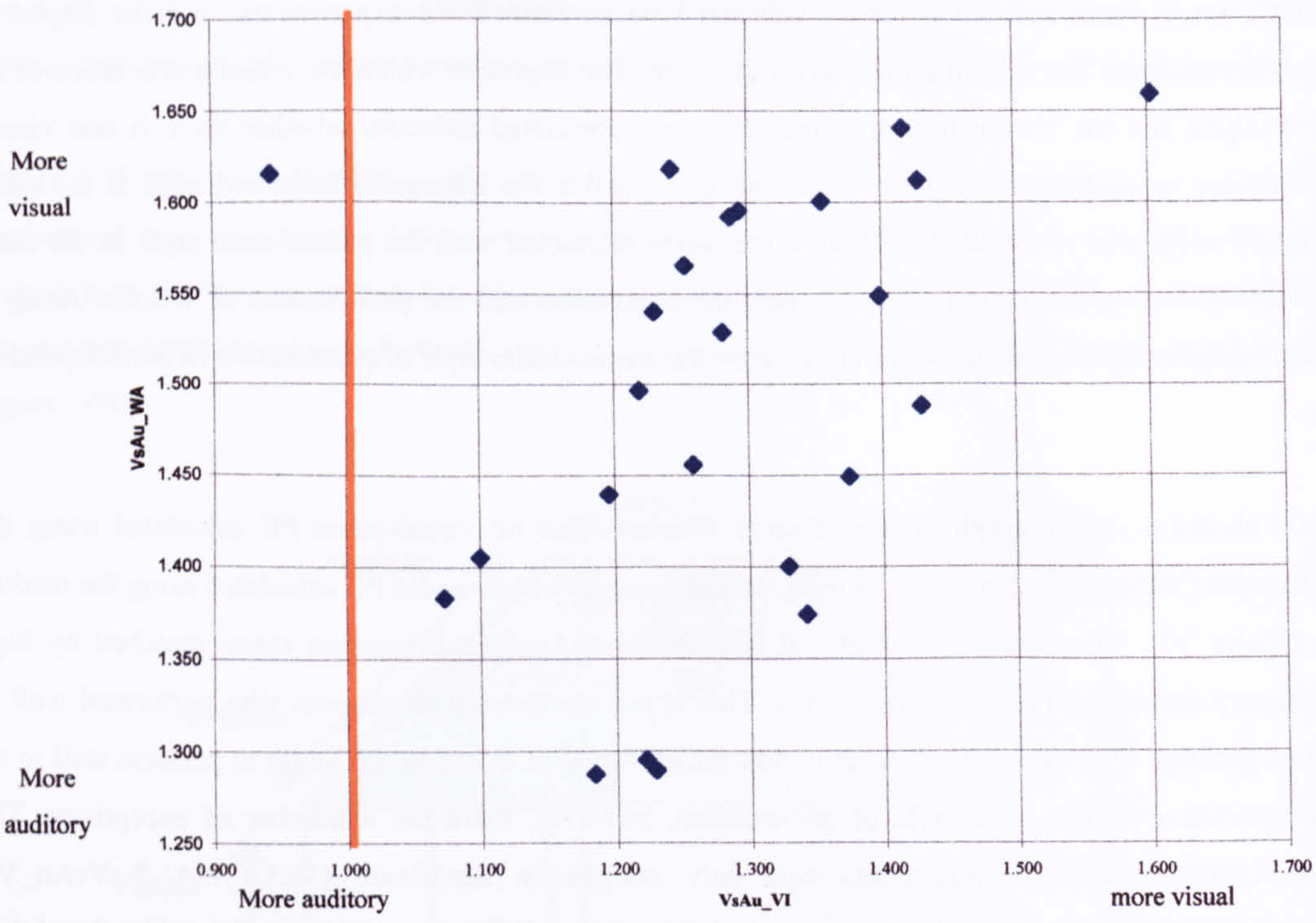


Figure 109: VsAu_WA * VsAu_VI scatter graph

The distribution of visual-audio PR ratios shown in figure 108 reflects the relative performance between the visual and audio experiments. It is possible to classify individual subjects as more visual or auditory for each dimension by determining whether they performed relatively well or poorly between the visual and audio experiments for each style of question. All subjects (except one) have visual-audio PRs that are above 1.00 which indicates that the visual experiment was performed better than the audio experiment. This may be because the duration figures in the audio experiment were longer than the visual experiment as subjects had to wait for the audio clips to be played rather than read the questions at their own pace. In order to identify whether subjects performed relatively better or worse using visual or audio information a more meaningful dividing point than 1.00 had to be established. Assuming that the twenty four subjects were a representative sample of the population a number of alternative dividing points can be identified.

	VsAu_VI	VsAu_WA
Average	1.279	1.495
Median	1.270	1.513
Mid Point	1.273	1.473

Table 106: Dividing points for the visual-audio style

Table 106 shows the possible dividing points for the visual-audio style for the Wholist-Analytic questions (VsAu_WA) and the Verbal-Imagery questions (VsAu_VI). The mid point is the point in the middle of the highest and lowest value. Most subjects, however are classified above this point. The difference in distribution between both dimensions is reflected by the median being lower than the average for the Verbal-

Imagery dimension and higher than the average for the Wholist-Analytic dimension. The median value was selected as the preferred dividing point as it removes the effect of abnormally high or low subject classifications.

The visual-audio ratio for both dimensions is combined with the visual Wholist-Analytic, the visual Verbal-Imagery, the audio Wholist-Analytic and audio Verbal-Imagery classification of subjects to give a more complete definition of CS. The new classification of visual and audio CS was used to see whether it was able to explain the performance of subjects in the first set of experiments. The results of this analysis is presented in the next sections.

8.4 Revisiting the previous sets of experiments

This section re-examines the performance of all subjects in the previous sets of experiments (chapters 4 to 7) in the light of the performance indicators identified in the results of the visual and audio experiments and examining the performance of individual subjects to see whether the extended classification of CS can explain their performance. Twelve subjects who performed the third experiment had performed the earlier experiments:

- four performed the first experiment
- eleven performed the second experiment

8.4.1 Individual subjects' performance in the first experiment

This section examines the performance of individual subjects in the first set of experiments to see whether their performance can be explained by their visual and audio classifications of CS as defined by the visual and audio experiments. Four of the subjects who performed the visual and audio experiments had also performed the first experiment. This section examines whether their visual-audio ratios affected their performance in the first experiment.

The visual and audio CSs of the four subjects as calculated in the visual and audio experiments are shown in table 107. The columns show the visual (Vs) and audio (Au) Wholist-Analytic (WA) and Verbal-Imagery (VI) classification of each subject listed by their ID number in the first set of experiments (3, 6, 12 and 16). The subjects' CS is indicated by the initial; Wholist (W), Analytic (A), Verbaliser (V) or Imager (I). The visual-audio ratio is displayed for the Wholist-Analytic (VsAu_WA) and Verbal-Imagery (VsAu_VI) dimensions indicating whether the subjects are more visual (Vs) or auditory (Au) based on the median dividing point between the visual-audio styles.

Subject ID	3	6	12	16
Vs_WA_MP	A	W	A	A
Vs_VI_MP	V	V	V	V
Au_WA_MP	A	A	A	W
Au_VI_MP	I	V	I	V
VsAu_WA	Vs	Au	Vs	Au
VsAu_VI	Au	Au	Au	Au

Table 107: Visual and audio classification of subjects

Subject ID	3	6	12	16
W * A Tasks	W	W	W	W
V * I Tasks	V	V	I	V

Table 108: Subjects performance by visual cognitive style

Subject ID	3	6	12	16
W * A Tasks	W	W	W	W
V * I Tasks	V	V	I	V

Table 109: Subjects performance by visual and auditory cognitive style

Tables 108 and 109 shows the relative performance of the four subjects (3, 6, 12 and 16) in the Wholist-Analytic tasks (W * A Tasks) and the Verbal-Imagery tasks (V * I Tasks) that were performed in the first experiment. The columns list the tasks that subjects performed best, Wholist (W), Analytic (A), Verbaliser (V) or Imager (I). The colour of background indicates whether the task that subjects performed best matched their CS (listed in table 107), with yellow indicating a match and red indicating no match. Table 108 shows whether performance matched their visual CS alone while table 109 shows whether performance matched their visual or auditory CS.

The relative performance in four out of eight pairs of task matched the visual CS of subjects (table 108), and this figure is increased to six out of eight when examining the visual and auditory CS of subjects (table 109). Subject number 6 performed the Wholist task better which was the same as their visual Wholist-Analytic style, while subject number 16 performed the Wholist task better which was the same as their audio Wholist-Analytic style (table 109). The other two subjects also performed the Wholist tasks better which did not match either their visual or audio Wholist-Analytic styles.

In the Verbal-Imagery tasks the performance of all subjects can be explained by their visual and audio CSs. Subjects 3, 6 and 16 performed the Verbaliser task better which matched their visual Verbal-Imagery style, and subject number 12 performed the Imager task better that matched their audio Verbal-Imagery style (table 109).

Some of the subjects performed the tasks in a manner that matched their visual CS while others matched their audio CS. This indicates that the relative influence of visual and audio style may be different for different subjects. The Verbal-Imagery visual-audio ratio of all subjects indicated that all performed better with the audio interface, while not all subjects performed the Verbal-Imagery task in a manner that matched their audio Verbal-Imagery style. While it is possible to explain the performance of subjects with reference to their visual and audio CS it was not possible to predict whether the visual or audio CS dimension would have more influence on performance in tasks that used visual and audio interfaces by examining the visual-audio ratio.

8.4.2 Individual subjects performance in the second experiment

This section examines the performance of individual subjects in the second set of experiments to test whether their performance can be explained by their visual and audio classifications of CS as defined by the visual and audio experiments. Eleven of the subjects who performed the visual and audio experiments had also performed the second set of experiments. This section examines their performance in the second experiment to determine whether their visual-audio ratios influenced their performance.

	1	6	13	15	19	21	23	30	31	32	41
WA Vs	A	A	A	A	A	A	W	A	A	A	W
VI Vs	V	I	V	I	V	I	I	V	V	I	I
WA Au	W	A	A	A	W	W	W	W	W	W	W
VI Au	V	V	V	V	V	V	I	I	I	V	I
WA VsAu	Vs	Au	Au	Au	Vs	Vs	Vs	Au	Au	Au	Vs
VI VsAu	Au	Vs	Au	Au	Au	Vs	Vs	Vs	Vs	Vs	Au

Table 110: Visual and audio classification of subjects

The visual and audio CSs of the eleven subjects identified by their ID number in the second set of experiments (1 to 44) as calculated in the visual and audio experiments are shown in table 109. The CS of subjects can be identified in the same manner as in table 107.

	1	6	13	15	19	21	23	30	31	32	41
T_PNC * T_PWC	T_PNC	T_PWC	T_PWC	T_PNC	T_PNC	T_PWC	T_PNC	T_PWC	T_PNC	T_PNC	T_PNC
I_TOB * T_POB	I_TOB	I_TOB	I_TOB	I_TOB	I_POB	I_TOB	I_TOB	I_POB	I_TOB	I_TOB	I_TOB
TI_PNC * T_PWC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PWC	TI_PWC	TI_PWC	TI_PNC	TI_PNC
A_PNC * T_PWC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PWC	A_PNC	A_PNC	A_PNC	A_PNC
V_GCO * V_DCO	V_DCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO
T_CON * T_OBJ	T_OBJ	T_CON	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ
A_CON * A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ
V_DCV * V_DCI	V_DCV	V_DCI	V_DCV	V_DCV	V_DCI	V_DCV	V_DCI	V_DCV	V_DCI	V_DCI	V_DCI
T_PNC * I_CFG	T_PNC	T_CFG	T_CFG	T_CFG	T_PNC	T_CFG	T_PNC	T_CFG	T_PNC	T_PNC	T_PNC
TI_PNC * CFG	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_CFG	TI_PNC	TI_CFG	TI_PNC	TI_PNC	TI_CFG	TI_PNC
A_PNC * I_CFG	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC
V_PRO * I_CFG	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO
A_PNC * TI_CFG	A_PNC	A_PNC	A_PNC	A_PNC	TI_CFG	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC
V_PRO * TI_CFG	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO

Table 111: Subjects performance by visual cognitive style

	1	6	13	15	19	21	23	30	31	32	41
T_PNC * T_PWC	T_PNC	T_PWC	T_PWC	T_PNC	T_PNC	T_PWC	T_PNC	T_PWC	T_PNC	T_PNC	T_PNC
I_TOB * T_POB	I_TOB	I_TOB	I_TOB	I_TOB	I_POB	I_TOB	I_TOB	I_POB	I_TOB	I_TOB	I_TOB
TI_PNC * T_PWC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_PWC	TI_PWC	TI_PWC	TI_PNC	TI_PNC
A_PNC * T_PWC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PWC	A_PNC	A_PNC	A_PNC	A_PNC
V_GCO * V_DCO	V_DCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO	V_GCO
T_CON * T_OBJ	T_OBJ	T_CON	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ	T_OBJ
A_CON * A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ	A_OBJ
V_DCV * V_DCI	V_DCV	V_DCI	V_DCV	V_DCV	V_DCI	V_DCV	V_DCI	V_DCV	V_DCI	V_DCI	V_DCI
T_PNC * I_CFG	T_PNC	T_CFG	T_CFG	T_CFG	T_PNC	T_CFG	T_PNC	T_CFG	T_PNC	T_PNC	T_PNC
TI_PNC * CFG	TI_PNC	TI_PNC	TI_PNC	TI_PNC	TI_CFG	TI_PNC	TI_CFG	TI_PNC	TI_PNC	TI_CFG	TI_PNC
A_PNC * I_CFG	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC
V_PRO * I_CFG	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO
A_PNC * TI_CFG	A_PNC	A_PNC	A_PNC	A_PNC	TI_CFG	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC	A_PNC
V_PRO * TI_CFG	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO	V_PRO

Table 112: Subjects performance by visual and auditory cognitive style

Tables 111 and 112 show the relative performance of the eleven subjects in the Wholist-Analytic tasks (W * A Tasks) and the Verbal-Imagery tasks (V * I Tasks) performed in the second experiment. The columns list which task the subject performed best. The colour of background indicates whether the task that subjects performed best matched their CS (listed in table 110). For table 111 the yellow background indicates a match with the visual CS and red indicates no match. For table 112:

- the yellow background indicates a match with the appropriate visual or auditory CS,
- the green background indicates no match with the appropriate visual or auditory CS but a match with the opposite visual or auditory CS,
- the blue background indicates a match with the visual-audio ratio and

- the red background indicates no match with either the visual or auditory CS.

The key to the task names is the same as in section 8.4.3.

Tasks are labelled in order of which CS group was expected to perform the tasks best. Wholist or Verbaliser style tasks are written first and Analytic or Imager style tasks are written second, for example in the first pair of tasks (T_PNC * T_PWC) the first task the text *procedural* task questions that do not include calculations (T_PNC) were expected to suit Wholists (chapter 5) while the second task the text *procedural* task questions that included calculations (T_PWC) were expected to suit Analytics (chapter 5).

The first three rows compare the performance of subjects in Wholist-Analytic tasks with a visual presentation.

- It was expected that subjects would perform better in the style of task that matched their visual Wholist-Analytic style.

The next row (A_PNC * A_PWC) compares the performance of subjects in Wholist-Analytic tasks with an audio presentation.

- It was expected that subjects would perform better in the style of task that matched their audio Wholist-Analytic style.

The next row (V_GCO * V_DCO) compares the performance of subjects in Wholist-Analytic tasks with a presentation that contains visual and audio information.

- It was expected that subjects would perform better in the style of task that matched either their visual or audio Wholist-Analytic styles.

The next row (T_CON * T_OBJ) compares the performance of subjects in Verbal-Imagery tasks with a visual presentation.

- It was expected that subjects would perform better in the style of task that matched their visual Verbal-Imagery style.

The next row (V_DCV * V_DVI) compares the performance of subjects in Verbal-Imagery tasks with a presentation that contains visual and audio information.

- It was expected that subjects would perform better in the style of task that matched either their visual or audio Verbal-Imagery styles.

The next two rows (T_PNC * I_CFG and TI_PNC * TI_CFG) compares the performance of subjects in Wholist-Analytic and Verbal-Imagery tasks with a visual presentation.

- It was expected that subjects would perform better in the style of task that matched either their visual Wholist-Analytic or Verbal-Imagery styles.

The last four rows compares the performance of subjects in Wholist-Analytic and Verbal-Imagery tasks between visual and audio presentation.

- It was expected that subjects would perform better in the style of task that matched either their visual or audio Wholist-Analytic or Verbal-Imagery styles.

When examining the performance of subjects classified only by their visual CS (table 111) half of the subjects performed in a manner that matched their CS (78 cells out of 154 with yellow backgrounds in table

111). This figure is increased to two thirds when matching performance with the visual and auditory CS of subjects (the 103 cells with the yellow backgrounds in table 112). Out of the third that were not performed as expected half were performed in a manner that matched the opposite visual or audio CS of subjects (the 26 cells with the green backgrounds in table 112). For these subjects the opposite visual or audio CS had more influence over their performance. Three of the calculations did not suit either the visual or audio CSs of the subject but did suit their visual-audio ratio as they performed the audio task better than the visual task which suited the visual-audio ratios for both their Wholist-Analytic and Verbal-Imagery dimensions (the cells with the blue backgrounds in table 112). The remaining 22 calculations did not match either the visual or audio Wholist-Analytic and Verbal-Imagery styles (the cells with the red backgrounds in table 112).

Only one subject performed all tasks as expected, being subject number 41 who was classified as a Wholist/Imager for both visual and audio classification. Other subjects who performed as expected in all but one or two calculations (subject number 30 and subject number 23) had different CS classifications which showed that the measurements were not biased for subjects with a particular CS classification.

While it is possible to explain the performance of most of the subjects between the tasks some of the tasks contained aspects that were suitable for styles from more than one dimension. In these cases it is possible to explain subjects performance by matching to one dimension without reference to the other dimension.

The visual and audio classification of CS is able to explain the performance of subjects in most cases but it is not precise and there are a large number of cases which are not explained by their classification in one dimension but were explained by their classification in another dimension, e.g. where a task is suitable for Wholists and Verbalisers and a Wholist/Imager subject performs the task well. It is not possible to predict the performance of subjects in these cases (i.e. predicting which dimension will be dominant in determining the performance of the subject). The classification of visual and audio CSs makes it easier to explain past behaviour but not to predict behaviour for complex tasks that have aspects that could suit more than one cognitive dimension and presents information using visual and audio interfaces.

8.5 Conclusion

This chapter described an experiment that attempted to determine whether CS effected the performance of individuals in the same manner when information is presented visually or is presented using audio. The use of median duration for calculating the PR was identified as more important than the average duration figure in the calculation of the CS ratio. The CS ratios calculated in the visual and audio experiments were not strongly correlated which indicated that the assessment of CS depended on whether visual or auditory information is used in the test. There was weak correlation between the visual-audio ratios produced for the Wholist-Analytic and Verbal-Imagery dimensions which indicates that there is a separate visual-audio ratio for both dimensions.

A new definition of CS was proposed that consisted of a visual Wholist-Analytic dimension, an audio Wholist-Analytic dimension, a visual Verbal-Imagery dimension, and an audio Verbal-Imagery dimension. Using the new definition of CS the performance of the majority of subjects in the first two sets of experiments were explained.

The conclusion of the experiment was that:

- there were differences in performance when information is presented visually or using audio.
- The effect of the visual and audio presentation constituted another dimension.
- The assessment of an individual's CS was extended from the original calculation of the visual Wholist-Analytic and Verbal-Imagery ratios to include a calculation of the audio Wholist-Analytic and Verbal-Imagery ratios and also a visual-audio Wholist-Analytic ratio and a visual-audio Verbal-Imagery ratio.
- This extended classification has implications on the value of adapting multimedia systems to suit the CS of users.

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9 Conclusions and suggestions for further research

The aim of this thesis was to investigate methods of providing support to non-expert users of telecare systems by creating easy-to-use interfaces and to assess the effect of adapting the interface to suit the cognitive style of individual users. The study primarily addresses the needs of telecare users but the findings may also have relevance for users of multimedia systems in general.

The first phase of the project involved an investigation into methods of providing support to users by implementing existing usability principles in a telecare prototype system. The second phase of the project was to derive new recommendations for designing interfaces that would be suitable for individual users based on how they perceive and process information. A series of experiments were conducted that investigated the effect that the cognitive style (CS) of users had on their performance in tasks where information is presented using different types of media. A series of recommendations of how to improve the performance of users can be derived from the results of these experiments. Interfaces should be created for each CS group containing more of the activities contained in the tasks that were performed relatively well and less of the activities contained in the tasks that were performed less well. In addition, a new definition of CS is proposed that includes a new visual-audio dimension. A persons' CS is classified using an existing visual test augmented by a new auditory test.

The original contribution to knowledge of this study are the innovations that are built into the prototype telecare system and the conclusions of the investigation into the interaction of CS and media.

9.1 Conclusions from the telecare companion prototype

The users of telecare systems are not expected to be expert computer users and have specific needs that require interfaces to be easy-to-use. A prototype telecare system was built that addressed the needs of the users by providing an easy-to-use interface and providing features that adapt to individual users.

The prototype was implemented to enable a range of features to be demonstrated. A review of the prototype enabled the identification of areas that required further investigation. The main phases of development of the prototype included:

1. the implementation of an easy-to-use interface.
2. the implementation of the adaptable features that enabled the system to be personalised by the user.
3. the implementation of the adaptive features that affected the selection of information to suit the goals and knowledge of the user.
4. the implementation of the adaptive features that affected the presentation of information that was suited to the CS of users.

The features that make the system easy-to-use that were implemented in the first phase of development include:

- The clear, consistent uncluttered layout of the screens.
- The main facilities are reached in a few simple steps.
- Navigational aids including the option buttons and menu bar.
- The design of large buttons, with extra functionality.
- The use of text, audio, text-to-speech and video to present information.
- The implementation of voice commands.
- The *companion* personality used to present information and assistance.

The development of the interface was based on existing usability principles, while the main innovations during the first phase were the implementation of the features that enabled Internet and email browsers to be controlled purely by using voice commands. The configuration of the system that enabled voice and images to be sent using a web server is also unique to the prototype.

The second phase of development involved the implementation of the adaptable features, including the selection of background images, music and size of font, by the users that enabled the system to become personalised by them.

The third phase of development involved the implementation of the adaptive features that automatically changed aspects of the interface to suit the needs of individual users. This involved implementing a method of automatically selecting the pieces of information that best suits the users' goals and current state of knowledge when the user requests help or browses through the general information stored on the system. The users' goals depended on where in the system they were, while their state of knowledge changed as they browsed through information. The rules for selecting items of information are based on existing adaptive techniques used in Intelligent Tutoring Systems but are placed in the new environment of telecare.

The fourth phase of development involved the implementation of the features that adapted the interface to suit the CS of users. This included developing alternative versions of items of information that were designed to suit different CSs and adapting the presentation style of the interface. The effect of CS on performance was chosen as an area that required further investigation. CS is a static attribute of the user and can be easily verified using an external test, while it is more difficult to identify dynamic attributes of the user such as their goals that may change many times within a session. The next section examines the conclusions from the experiments that examined the effect of CS on the performance of the user and tested the accuracy of the assessment of CS implemented within the prototype.

9.2 Conclusions from the cognitive style experiments

The experiments attempted to determine:

- whether performance of users is enhanced by adapting the interface to suit their CS, and

- can the CS of users be determined by monitoring their actions.

Three sets of experiments were conducted assessing the performance of CS groups with interfaces and tasks that were designed to suit different CS groups. The first experiment examined the performance of subjects in general tasks using multimedia while the other experiments focused on less complex tasks using individual types of media.

1. The first experiment was set up to test the assumption that subjects would perform relatively better at tasks that were designed to suit their own CS and relatively worse at tasks that were designed to suit the opposite style. The results of the experiment produced some evidence that CS was influencing performance, however this was not always in the expected manner. No significant differences were detected between the CS groups in the measures that monitored the actions of users, therefore CS could not be assessed accurately using the types of actions that were monitored in the prototype. The conclusion was that other factors were influencing the performance of subjects. The main difference between the experiment and the CSA test was the mode of presentation and the structure of the tasks.

2. The second experiment attempted to remove the problems built into the first experiment by reducing the complexity of the tasks and reducing the complexity of the presentation style by presenting information using single media. A series of media tests were prepared to explore whether the performance of the CS groups was affected by the choice of media used to present information. The performance of subjects was calculated using a performance ratio of score divided by duration. The performance of subjects was examined by comparing the relative performance of the CS groups within each task and comparing the relative performance of each CS group between the tasks.

The performance of subjects in the experiment were used to test the hypotheses that:

- A persons' CS will affect their performance in a predictable manner when performing tasks that use the same media that are used in the CSA test.
- A persons' CS will affect their performance in a predictable manner when processing information using the same parts of the brain that were used during the CSA test.
- A persons' CS will not affect their performance in a predictable manner when processing information using different parts of the brain that were used during the CSA test.

The results of the experiment were inconclusive. There were relatively few tasks in which the performance of the CS groups was significantly different.

- There was no evidence to support the hypotheses when comparing performance in the tasks that were directly comparable with the CSA test and used the same media as the CSA test.
- There was no evidence to support the hypotheses when comparing performance in the tasks that used the same media as the CSA test. The CS groups performed only two tasks significantly differently and these tasks were performed in an opposite manner to the prior expectation.

- There was little evidence to support the hypotheses when comparing performance in the tasks that used the different media as the CSA test. The CS groups performed only four tasks significantly differently and of these two were performed as predicted and two were performed in an opposite manner to the prior expectation.

The media type appeared to have more influence on performance than the structure of information as more significant differences were found between Verbalisers and Imagers than between Wholists and Analytics.

A series of tables were compiled for each CS group showing the tasks ranked by performance and indicating which tasks were performed significantly differently. Two sets of tables were produced, one showing the relative performance of each CS group between the tasks performed within each media test and the other showing their relative performance in individual tasks between the media tests. These tables can be referred to when designing interfaces that best suit each CS group to maximise the performance of each group. Interfaces can be created for each CS group that contain more of the activities contained in the tasks that were performed best and less of the activities contained in the tasks that were performed worst. Also an assessment of the CS of users can be made by monitoring the relative performance in similar tasks by matching their relative performance with the relative performance of each CS group.

The relative difference in performance between the tasks is explained by the types of activities that are performed in each task. Relatively simple tasks are performed well and relatively complex tasks are performed less well. Where the nature of the task is equivalent relative differences between the CS groups depends of the CS groups themselves. The differences between the CS groups were not all explained by the expected performance of the CS groups.

A number of reasons were explored to explain why the tasks were not all performed as expected, including:

- The CSA test uses a large number of questions to assess the performance of each CS group while there were smaller numbers of questions in each task.
- The CSA test used simple tasks that contained aspects that were suitable for only one CS group while the experiment tasks were more complex and some contained aspects that suited different CS groups in more than one dimension.
- Performance in the CSA test appears to be assessed using the relative time it takes to answer two styles of question while in the experiment performance is measured for individual tasks using a performance ratio of score divided by duration.

3. The third experiment examined the performance of subjects when the three above factors were addressed in the design of the experiment. A large number of questions were used in tasks that did not contain aspects that were suitable for more than one CS group and a number of different measures of performance were recorded. The experiment examined whether CS affected the performance of individuals in the same manner when information is presented visually or is presented using audio. The performance of subjects in a visual

test that used the same questions as the CSA test was compared against their performance in a new auditory test that contained equivalent questions.

Performance ratios for the Wholist-Analytic and Verbal-Imagery dimensions were calculated for the visual and auditory tests and the correlation between these ratios and the ratios produced by the original CSA test were calculated. In addition visual-audio ratios were produced for both dimensions by comparing the performance in the visual and audio tests. The main results of the experiment are summarised as:

- Performance ratios calculated using the median duration were found to be more closely correlated with the CSA ratios than performance ratios calculated using the average duration figure.
- There was low correlation between the CS ratios calculated in the visual and audio tests, which indicated that the perception of auditory and visual information were controlled by different CSs.
- There was low correlation between the Visual-Audio ratios produced for the Wholist-Analytic and Verbal-Imagery dimensions which indicates that there is a separate Visual-Audio ratio for both dimensions.

A new definition of CS was proposed that consisted of:

- a Visual Wholist-Analytic dimension,
- an Audio Wholist-Analytic dimension,
- a Visual Verbal-Imagery dimension, and
- an Audio Verbal-Imagery dimension.

A visual-audio ratio can also be calculated for both the Wholist-Analytic and Verbal-Imagery dimensions that reflects the difference between the visual and audio ratios.

The performance of individual subjects in the first two sets of experiments were re-examined to see whether their performance can be explained by their visual and audio classifications of CS. The relative performance of subjects between pairs of tasks that were designed to suit opposite CSs were examined. Less than half of the tasks were performed as expected by subjects classified by the old visual definition of CS while the majority of tasks were performed as expected by subjects classified by the new visual and audio definition of CS. The visual and audio classification of CS explains more past behaviour than the old purely visual classification, however, the visual-audio ratios did not help predict performance in more complex tasks that presented information using a combination of media where the visual and audio classification of the Wholist-Analytic or Verbal-Imagery dimensions is not the same.

9.3 Contributions to knowledge

There are three areas in which this thesis made contributions to knowledge; the innovations that are built into the prototype adaptive telecare system, the identification of the sort of tasks and media that will improve the performance of each CS group, and the identification of a new visual-audio dimension of CS.

The innovations built into the prototype telecare system are mainly related to the use of existing technology within the new environment of telecare. The system allows users to control the system, including the email and Internet browsers, using voice commands, and allows the contents of emails and web pages to be read out by text-to-speech. There are a number of products that are currently available that offer assistance to users with disabilities to browse the Internet using voice commands with text-to-speech output. Some, like BrookesTalk (Zajicek, et al., 1999) and pwWebSpeak (Browne, 1997) are stand alone web browsers, while others, such as Marco Polo (Sonicon, 1996) and HomePage Reader (IBM, 1998) are add-ins to other web browsers. Telecare Companion offers these facilities within a wider telecare system. The *companion* personality is used throughout the system, within the help systems and offering general information to the users. The *companion* is embedded into the information presented to the user (HTML files, images and video clips), while using the Microsoft Agent technology (Microsoft, 2002) it is now possible to program a similar character that could remain on screen at all times as a separate entity, monitoring user actions and interacting with the telecare system. Further developments of the companion would investigate this method of interaction between the user and the system.

This thesis identified the sort of tasks and media that will improve the performance of each CS group. The CSA manual offers general advice of how to improve the performance of individuals in the different CS groups, and further inferences can be drawn from the associated literature, however the recommendations in this thesis are more focused, identifying the specific tasks and media that are shown to suit each CS group. Developers of multimedia systems can use this information to create interfaces and tasks that would enable each CS group to improve their performance, by selecting the tasks that are ranked high.

The CSA test uses duration to assess the performance of individuals. This thesis improves the assessment of performance by calculating a ratio of score over duration. For individuals to achieve a high performance ratio they have to score high in a short duration.

This thesis proposes a new dimension to the definition of CS. Individuals are classified by their perception of information presented visually (the CSA test) plus their perception of information presented using audio. The test described in chapter 8 can be used to classify individual's auditory CS dimensions. The original CSA test was produced as a visual computerised test before the widespread use of multimedia PCs, but now computer environments are more complex and the old CSA classification does not adequately explain the performance of computer users. The new classification of CS is an advance on the old purely visual classification as it takes into account the perception of different types of media and so better reflects the new context. The visual and auditory classification of CS has been shown to better explain the performance of individuals who performed the experiments reported in this thesis.

9.4 Suggestions for further research

The telecare prototype was developed to a sufficient level in order to demonstrate aspects of telecare and to identify areas that required further research. No more development is required on the prototype system as a whole, however, stand-alone aspects of the system could be developed and tested in light of the results of the cognitive style experiments, such as implementing alternative versions of tasks for different CS groups that are based on the recommendations in chapter 6 and 7.

CS was chosen as the main area of interest for this study, however there may be many other areas associated with the prototype that could be chosen for further investigation:

- Rating the features of the system. What are the most useful aspects, and what features are missing.
- Testing the use of voice commands. Assess how easy it is to read email or to browse the Internet using voice commands alone.
- The assignment of the goals of users. In the prototype it is assumed that users want to know about the part of the system that they are currently in, however this may not be the case as they may want to know how to access another feature. A more sophisticated mechanism of assessing user goals is required, such as offering a simple choice when requesting help, which may include a list based on their previous interaction.
- The assessment of the user's current state of knowledge. If a particular item of information has been displayed it is assumed that the user knows it's contents, which may not be the case. A test of user knowledge is required. Intelligent Tutoring Systems have built in tests which may not be appropriate for telecare so the testing has to be more subtle, such as offering choices to users while browsing the items of information (if the user makes a *wrong* choice the system can assume that the user does not fully understand a certain concept and so should be offered additional information).
- Assessing the CS of users. The assumptions implemented in the prototype, e.g. Imagers are more likely to select image links while Verbalisers are more likely to select text links, were found to be incorrect by the CS experiments, therefore more research is needed to discover traits that can be reliably associated with the CS groups. This may involve matching the relative performance of users with the performance of tasks identified in the CS experiments.

The experiments were performed by enough subjects to produce reliable statistics for comparing the performance of Wholists against Analytics and Verbalisers against Imagers, but not the performance of the CS quadrants against each other. The results of the experiments showed the importance of considering the combined influence of both dimensions on the performance of subjects. More subjects are needed to perform the experiments in order to compare the performance of the CS quadrants. Also new tasks need to be devised that contain attributes that are suitable for each quadrant.

More research is needed to verify the existence of the Visual-Audio dimension of CS. The relative influence of the visual and audio CS was found to vary between individuals. This needs to be examined in order to predict which dimension exerts greater influence on the performance of subjects when information is presented using a mixture of media.

CS was chosen as the attribute of the user that was investigated in this study while other aspects of the user could be investigated such as:

- The attention span of the user.
- The preferred locus of control of the user.
- Dynamic attributes of the user such as their goals and their current state of knowledge.

Appendix 1: Blood Pressure Tutorial

- The purpose of this tutorial is for you to learn how to measure the blood pressure in your brachial artery, using a sphygmomanometer.
- Blood pressure is the force created by the heart as it pushes blood through arteries and veins, against the force of the arteries as they resist the blood flow.
- The blood pressure has two different pressure readings. Systolic pressure is the higher reading that occurs as your heart beats and pumps blood through your body. Diastolic pressure is the lower reading that occurs when your heart is resting between beats.
- The blood pressure is measured in millimetres of mercury (mm Hg).
- The systolic pressure written first, followed by a slash mark, and the diastolic pressure.
- Equipment used to measure blood pressure includes a stethoscope and a sphygmomanometer, containing a mercury gauge, a cuff and a rubber bulb with valve.
- Prepare yourself before taking a reading. Sit and relax for 5 to 10 minutes. Do not talk. Remove any constrictive articles, such as clothing or jewellery that might interfere with placement of the cuff. Sit in a comfortable position, with your back supported, and your legs and ankles uncrossed.
- Put the stethoscope ear pieces into your ears, with the ear pieces facing forward.
- Wrap the cuff smoothly around the upper part of your right arm. There should be enough room for you to slip one fingertip under the cuff. The bottom edge of the cuff should be one inch above your elbow.
- The right arm is normally used for readings as the left arm often produces readings of 10 to 20 millimetres of mercury lower.
- Your brachial artery is the large blood vessel that goes from your shoulder to just below your elbow. It can be located on your arm above the inside of your elbow crease, on the side nearest your body.
- Line up the arrow on the cuff with your brachial artery.
- Place your arm, raised to the level of your heart, on a table or a desk, and sit still.
- Stimulate your brachial artery to make it stand out by pushing it up and down with your left hand.
- Close the valve on the rubber bulb.
- Inflate the cuff by squeezing the rubber bulb. The cuff should be inflated rapidly as inflating the cuff too slowly will cause a false reading.
- Watch the mercury rise on the sphygmomanometer gauge. The cuff should be inflated to about 180 millimetres of mercury. Do not exceed 280 millimetres of mercury.
- When the cuff is inflated, it compresses the brachial artery, momentarily stopping the flow of blood.
- Place the listening end of the stethoscope onto the brachial artery.
- Slightly loosen the valve and slowly let some air out of the cuff.
- Watch the fall on the sphygmomanometer gauge. Deflate the cuff at a rate of 2 to 3 millimetres per second. If you loosen the valve too much, you will not be able to determine your blood pressure.
- Listen carefully with the stethoscope for your heartbeat. When the blood starts to pulse through the artery, it makes a sound.
- Make a note of the mercury level on the sphygmomanometer gauge when this sound is first heard. This is your systolic blood pressure. On average this will occur at 120 millimetres of mercury.
- Continue to let air out of the cuff at the same level, and listen to your heartbeat.
- Your heartbeat will continue to be heard until pressure in the artery exceeds the pressure in the cuff.
- Make a note of the mercury level on the sphygmomanometer gauge when the sound of your heartbeat disappears. This is your diastolic blood pressure. On average this will occur at 80 millimetres of mercury.
- Open the valve fully and let the remaining air out of the cuff.
- Write down your blood pressure putting the systolic pressure before the diastolic pressure, resulting in a number such as 120/80.
- If you want to repeat the measurement, rest 3 to 5 minutes before re-inflating the cuff.

Appendix 2: Blood Pressure Tutorial Questions

No.	Question	Answer
1	*What is the name of the medical equipment used to measure your blood pressure?* A. *a shygnomanometer,* B. *a shygmomanometer, or* C. *a svigmomanneometre?*	B
2	*Blood pressure is the force created by what?* A. *The heart as it pushes blood through arteries and veins,* B. *the force of arteries as they resist blood flow, or* C. *the heart as it pushes blood through arteries and veins, against the force of arteries as they resist the blood flow?*	C
3	*What is diastolic pressure?* A. *The lower reading that occurs when your heart beats and pumps blood through your body,* B. *the lower reading that occurs when your heart rests between beats, or* C. *the higher reading that occurs when your heart beats and pumps blood through your body?*	B
4	*What is systolic pressure?* A. *The higher reading that occurs when your heart beats and pumps blood through your body,* B. *the higher reading that occurs when your heart rests between beats, or* C. *the lower reading that occurs when your heart beats and pumps blood through your body?*	A
5	In what units is blood pressure measured? A. Millimetres of mercury, B. Metres of mercury, or C. Micrometres of mercury?	A
6	*How is blood pressure written?* A. *diastolic / systolic,* B. *systolic / diastolic, or* C. *No preference to which is written first?*	B
7	*Are there any differences between the readings of the left and right arms?* A. *Yes, the right arm gives readings of between 10 to 20 mm Hg higher, yes,* B. *the right arm gives readings of between 10 to 20 mm Hg lower, or* C. *no, pressure is the same throughout the body?*	B
8	*How long should you relax before taking a reading?* A. *Between 5 - 10 minutes,* B. *between 3 - 5 minutes, or* C. *it makes no difference?*	A
9	*How tight should the cuff be?* A. *As tight possible,* B. *tight enough not to allow a finger tip under the cuff, or* C. *loose enough to allow a finger tip under the cuff?*	C
10	*How should you relax before taking a reading?* A. *Sit upright with your ankles crossed,* B. *sit with your back supported, or* 1. *lie down with your arms raised above the level of your heart?*	B
11	*Where can your brachial artery be found?* A. *It can be located on your arm above the inside of your elbow crease, on the side nearest your body,* B. *it can be located on your arm above the inside of your elbow crease, or* C. *in the middle or it can be located on your arm above the inside of your elbow crease, on the side furthest from your body?*	A
12	*When should you stimulate your brachial artery?* A. *After putting on the cuff,* B. *after inflating the cuff, or* C. *before putting on the cuff?*	C
13	*After closing the valve, how fast should the cuff be inflated?* A. *As fast as possible,* B. *at a rate of 2 to 3 millimetres per second, or* C. *gently?*	A
14	*When should you stop inflating the cuff?* A. *When you hear your pulse stop, or* B. *when mercury on the sphygmomanometer gauge reaches 180 mm Hg or* 1. *after the mercury on the sphygmomanometer gauge reaches 280 mm Hg?*	B
15	*Where should the cuff be placed on your arm?* A. *One inch from your arm pit,* B. *one inch from your elbow, or* C. *one inch from your elbow crease?*	B
16	*When you first hear your pulse how fast should you let air out of the cuff?* A. *Open the valve fully and let the remaining air out of the cuff,* B. *stop letting air out until the diastolic pressure is detected, or* C. *at a rate of 2 - 3 millimetres of mercury per second?*	C
17	*What is an average blood pressure reading for a healthy male adult?* A. *120/80,* B. *140/90, or* C. *180/120?*	A

18	*When is systolic blood pressure detected?* A. *When the blood starts to pulse through the artery,* B. *when pressure in the artery exceeds the pressure in the cuff, or* C. *when the sound of your heartbeat disappears?*	A
19	How soon is it safe to take another reading? A. After 5 - 10 minutes, B. only take one reading a day, or C. after 3 - 5 minutes?	C
20	*How can you regulate the pressure in the cuff.* A. *By keeping the rubber bulb squeezed,* B. *by opening and closing the valve, or* C. *by rapidly squeezing the rubber bulb and letting air leak out of the cuff.*	B

Appendix 3: Family & Friends Data

Name:	Henry Talbot
Relationship:	Friend from work
Address:	26 Westover Road, Bournemouth, Dorset, England
Telephone:	01202 785321
E-mail:	dr_2000@bournemouth.ac.uk
Videophone:	01202 785322
Anniversaries:	Graduation 21 Oct 1994, Moving House 12 Jun 1997
Media:	 Portrait: Fire.jpg  Holiday: Eifel.jpg
Name:	Anne Brown
Relationship:	Mother
Address:	10 Kings Road, Harrogate, North Yorkshire, England
Telephone:	01372 769217
E-mail:	None
Videophone:	None
Anniversaries:	Birthday 15 Apr 1936, Wedding Anniversary 26 Nov 1959
Media:	 Family: 1957.avi  Pet: Puppy.jpg

Appendix 4: Text Experiment Questions

Comparison of objects (Imager)

No.	Question	Answer
1	*Duck and Goose are the same type*	True
4	*Cat and Mouse are the same size*	False
5	*Tree and Bush are the same colour*	True
7	*Doctor and Stethoscope are the same type*	False
8	*Igloo and House are the same type*	True

Comparison of concepts (Verbaliser)

No.	Question	Answer
2	*Walk and Run are the same type*	True
3	*Spend and Save are the same type*	False
6	*Fly and Glide are the same type*	True
9	*Swimming and Costume are the same type*	False
10	*Background and Camouflage are the same colour*	True

Mathematics (Analytic & Verbaliser)

No.	Question	Answer
11	*Add eight and six*	14
12	*Multiply four and six*	24
13	*Divide twenty four by three*	8

Procedural without calculations (Wholist & Verbaliser)

Information:

Take the first right (which is about one hundred yards ahead). Keep going for sixty yards, and turn right at the cross roads. The library is on the left about seventy yards further on.

No.	Question	Answer
15	*How Many times do you turn a left corner?* A. *0,* B. *1, or* C. *2?*	A
16	*How Many times do you turn a right corner?* A. *0,* B. *1, or* C. *2?*	B
18	*How Many times do you turn a left corner?* A. *0,* B. *1, or* C. *2?*	B

Procedural with calculations (Analytic & Verbaliser)

No.	Question	Answer
14	*How far away is the library?* A. *One hundred and thirty yards,* B. *One hundred and seventy yards, or* C. *Two hundred and thirty yards?*	C
17	*How far are the traffic lights?* A. *One hundred and eighty yards,* B. *One hundred and seventy yards, or* C. *Two hundred and sixty yards?*	C

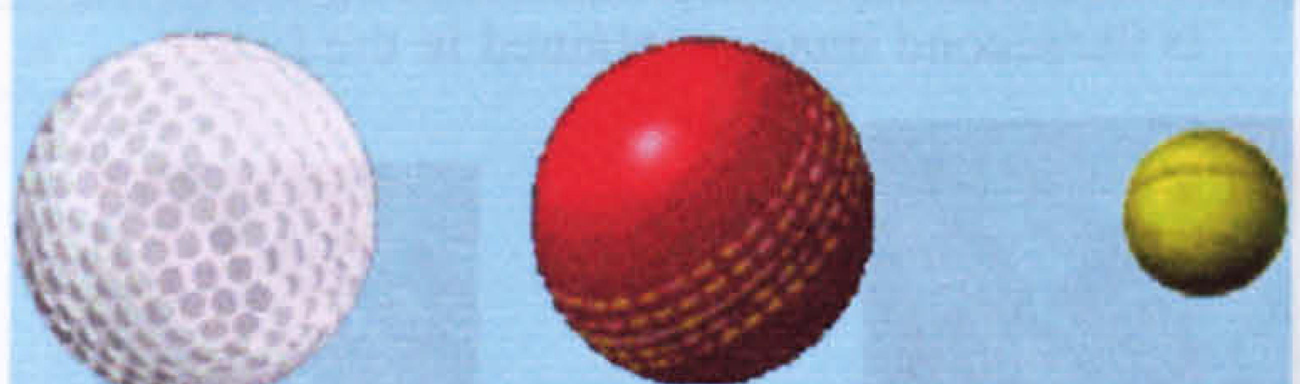
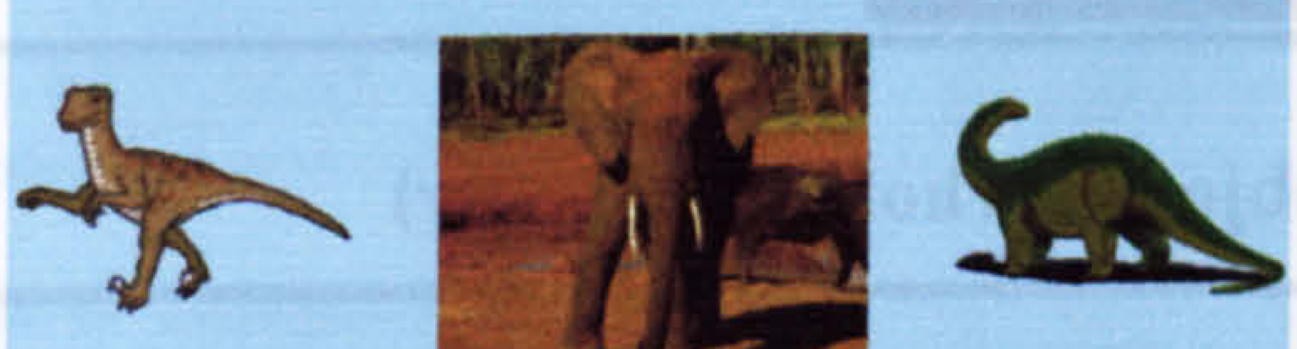
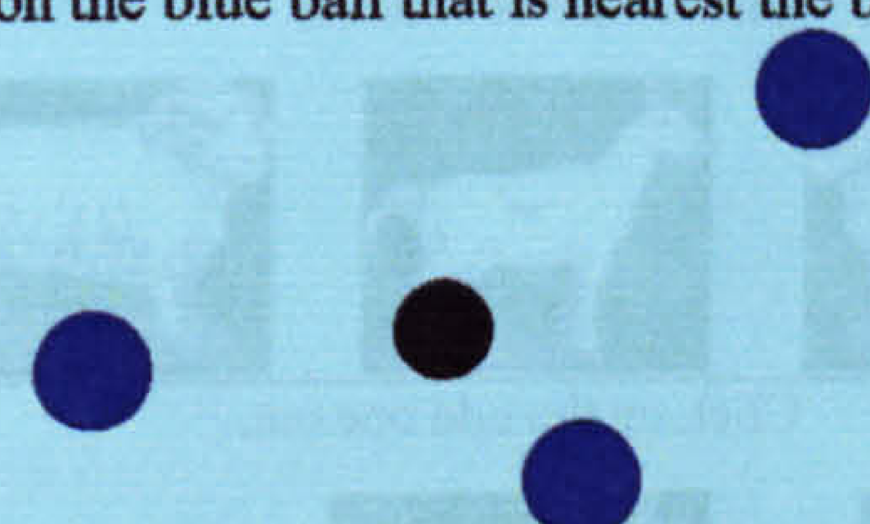
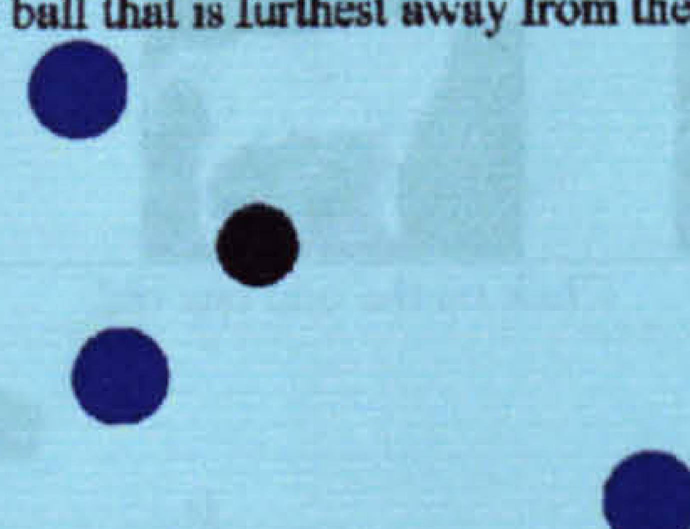
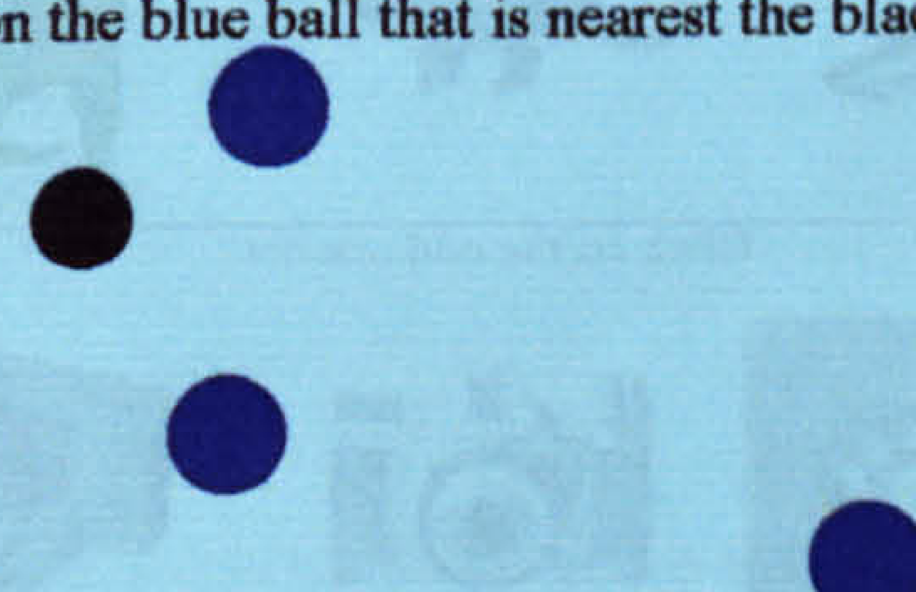
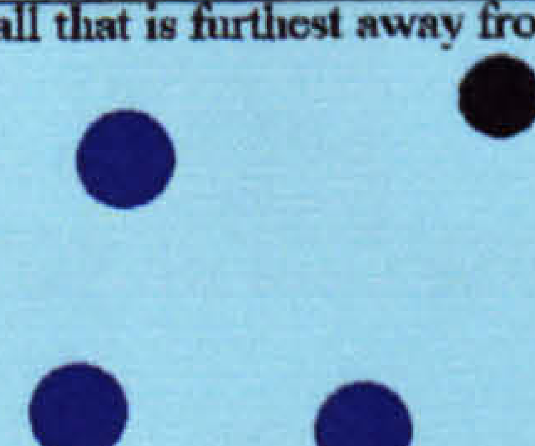
Comprehension (Analytic & Verbaliser)

Information 1:		
• *Mr. Oak carried about him, by way of watch, what may be called a small silver clock; in other words, it was a watch as to shape and intention, and a small clock as to size.* • *This instrument being several years older than Oak's grandfather, had the peculiarity of going either too fast or not at all.* • *The smaller of its hands, too, occasionally slipped round on the pivot, and thus, though the minutes were told with precision, nobody could be quite certain of the hour they belonged to.*		
No.	Question	Answer
19	*What size was Mr. Oak's watch?* A. *Small,* B. *Normal, or* C. *Large?*	C
20	*How old was Mr. Oak's watch?* A. *Older than his grandfather,* B. *As old as grandfather, or* C. *Not as old as his grandfather?*	A
21	*How accurate was the watch?* A. *Too slow,* B. *Accurate, or* C. *Too fast?*	C
22	How many defects of the watch are listed? A. *2,* B. *3, or* C. *4?*	C
23	*Which of the watch hands was faulty?* A. *The hour hand,* B. *The minute hand, or* C. *The second hand?*	A

Information 2:		
• *Pathology is the branch of medicine concerned with determining the nature and course of diseases by analysing body tissues and fluids.* • *Anatomic pathologists perform autopsies and analyse tissues taken from patients during surgery or by biopsy.* • *Clinical pathologists contribute to the diagnosis of disease by measuring chemicals and cells in blood, sputum, bone marrow, and urine.*		
No.	Question	Answer
24	*What is the purpose of pathology?* A. *To determine the cause of,* B. *To analyze body tissues and fluids, or* C. *To determine nature of disease?*	C
25	Which type of pathologist perform autopsies? A. *Clinical pathologists,* B. *Anatomic pathologists, or* C. *They both do?*	B
26	*Which do clinical pathologists measure?* A. *Chemicals and cells,* B. *blood and sputum, or* C. *bone marrow and urine?*	A

Appendix 5: Image Experiment Questions

Comparison of physical attributes of objects (Analytic & Imager)

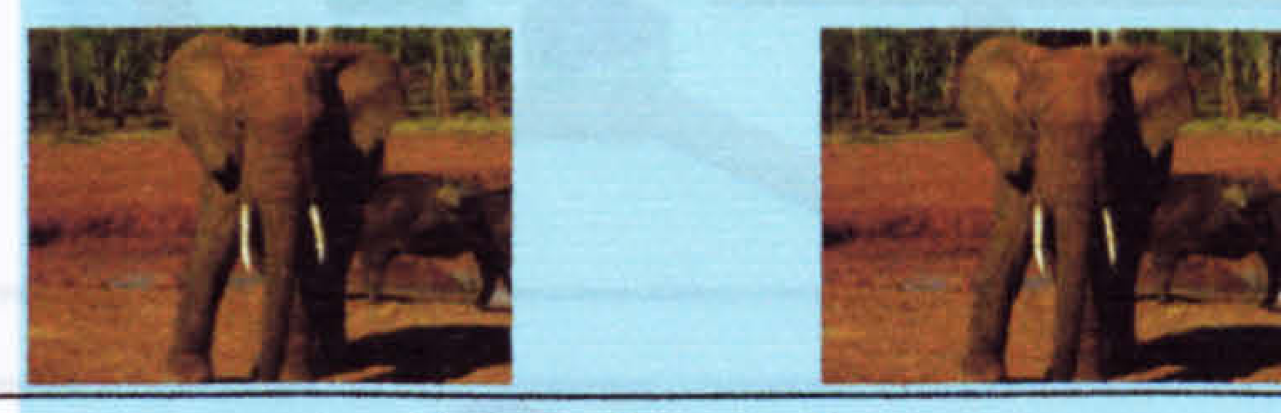
No.	Question	Answer
1	Click on the largest ball image. 	3
2	Click on the tallest building image. 	2
3	Click on the smallest ball image. 	3
4	Click on the smallest animal image. 	3
5	Click on the blue ball that is nearest the black ball. 	2
6	Click on the blue ball that is furthest away from the black ball. 	3
7	Click on the blue ball that is nearest the black ball. 	1
8	Click on the blue ball that is furthest away from the black ball. 	2

22		No
23		Yes
24		No
25		Yes

Comparison of types of objects (Wholist & Imager)

No.	Question	Answer
14		2
15		2
16		3
17		1

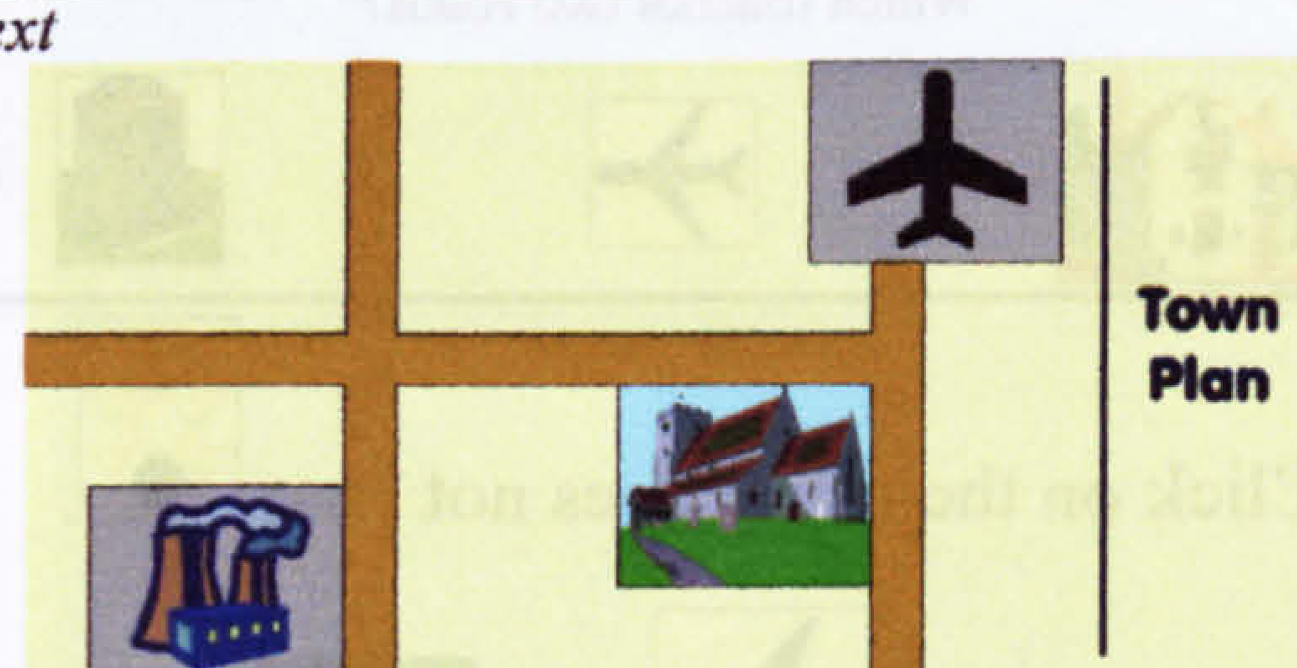
Comparison of objects (Analytic & Imager)

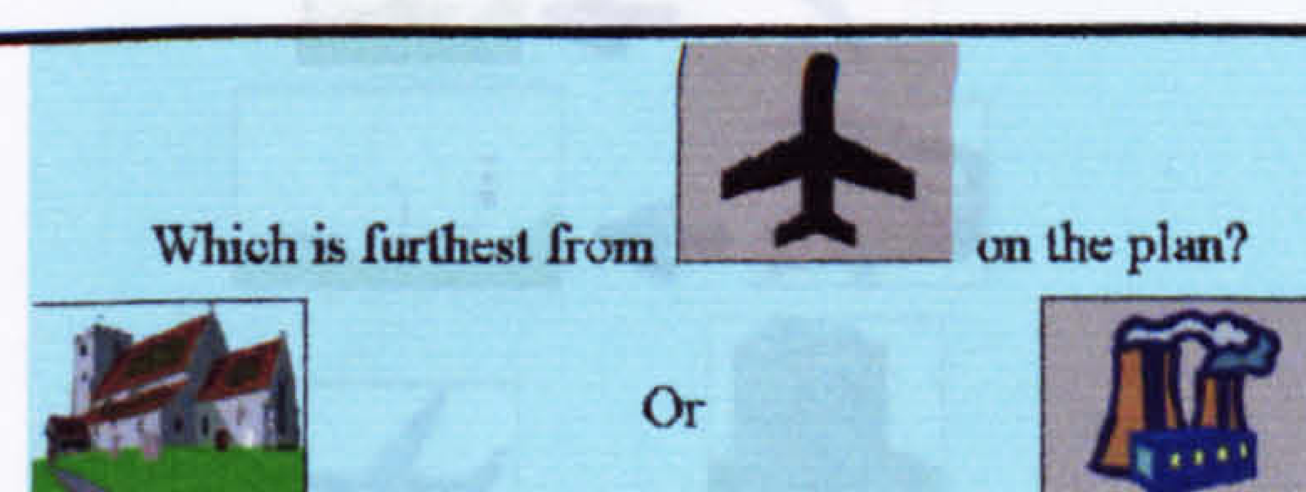
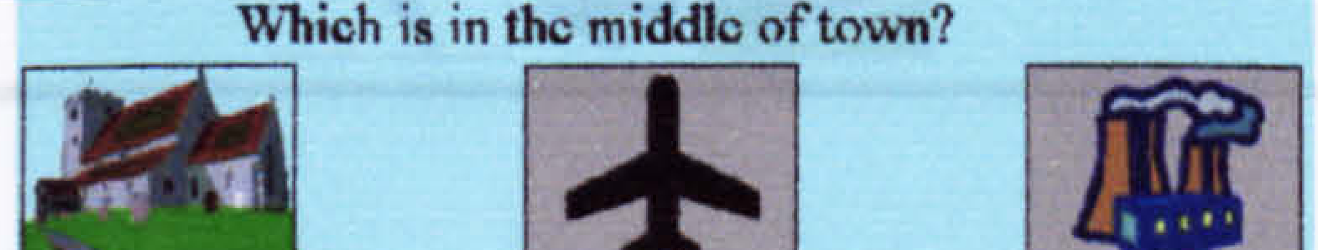
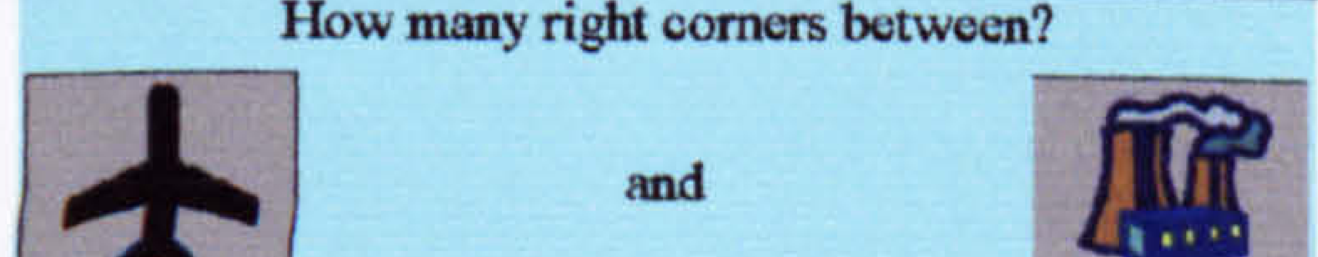
No.	Question	Answer
18	Are the two images the same. 	No
19	Are the two images the same. 	Yes
20	Are the two images the same. 	No
21	Are the two images the same. 	No

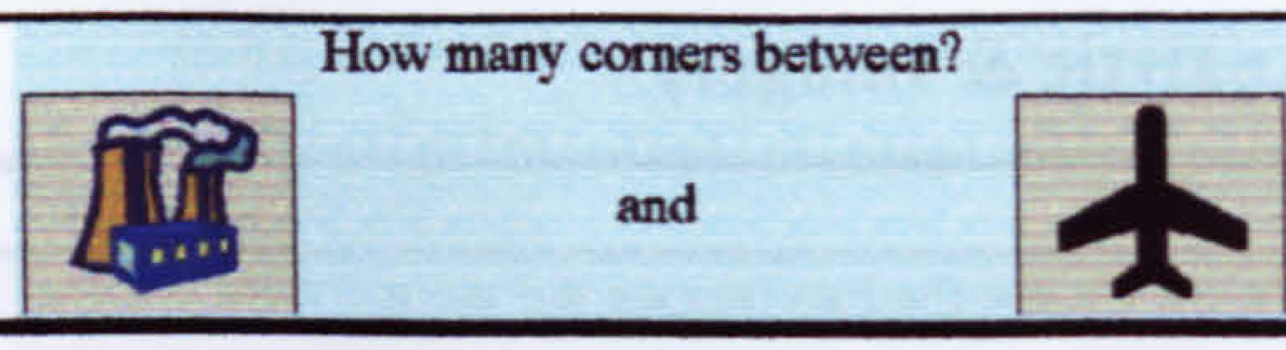
Configuration (Analytic & Imager)

Information 1:

Study the map and click on Next

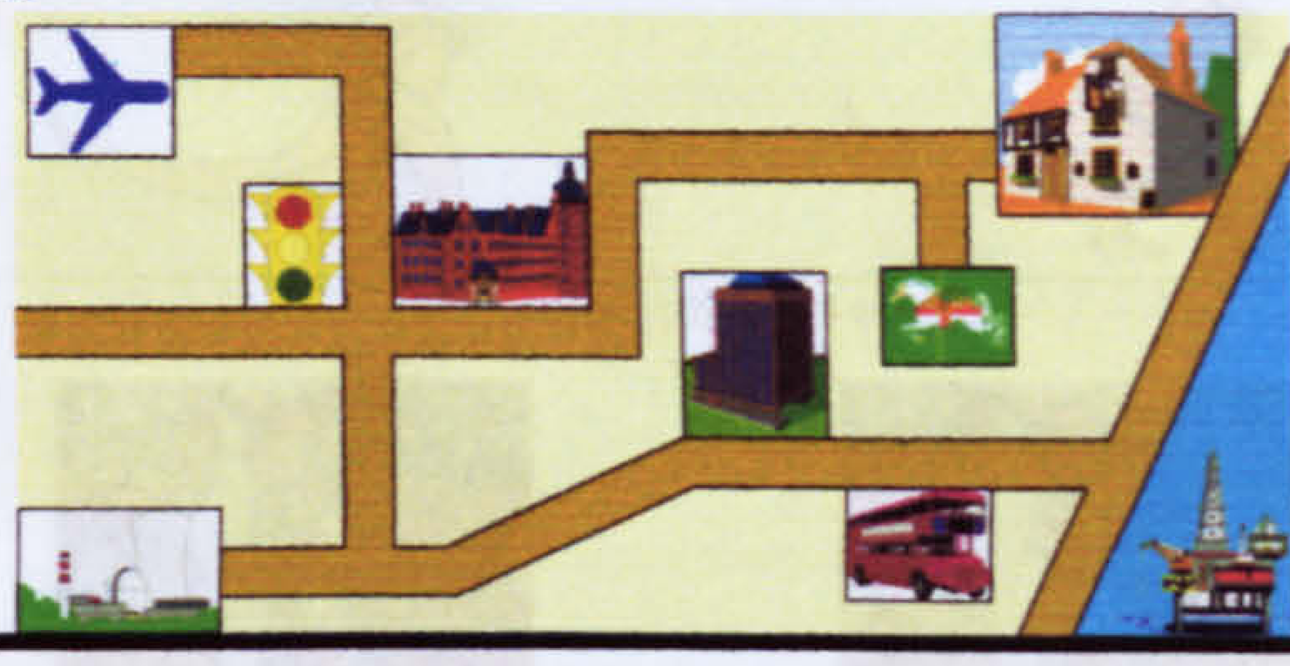


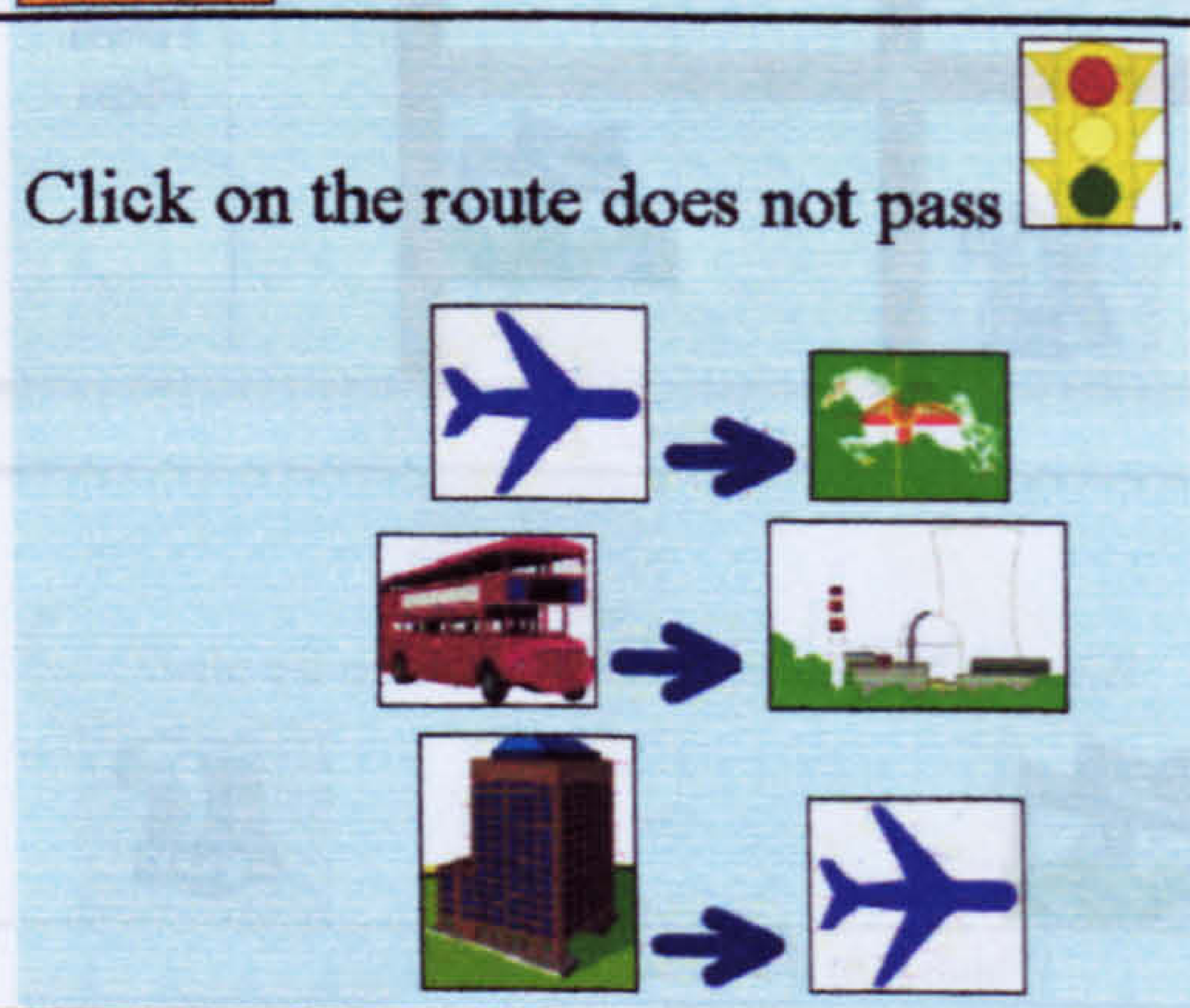
No.	Question	Answer
9		2
10	Which is in the middle of town? 	1
11	Which is on the bottom left of the map? 	3
12	How many right corners between? 	1

13		2

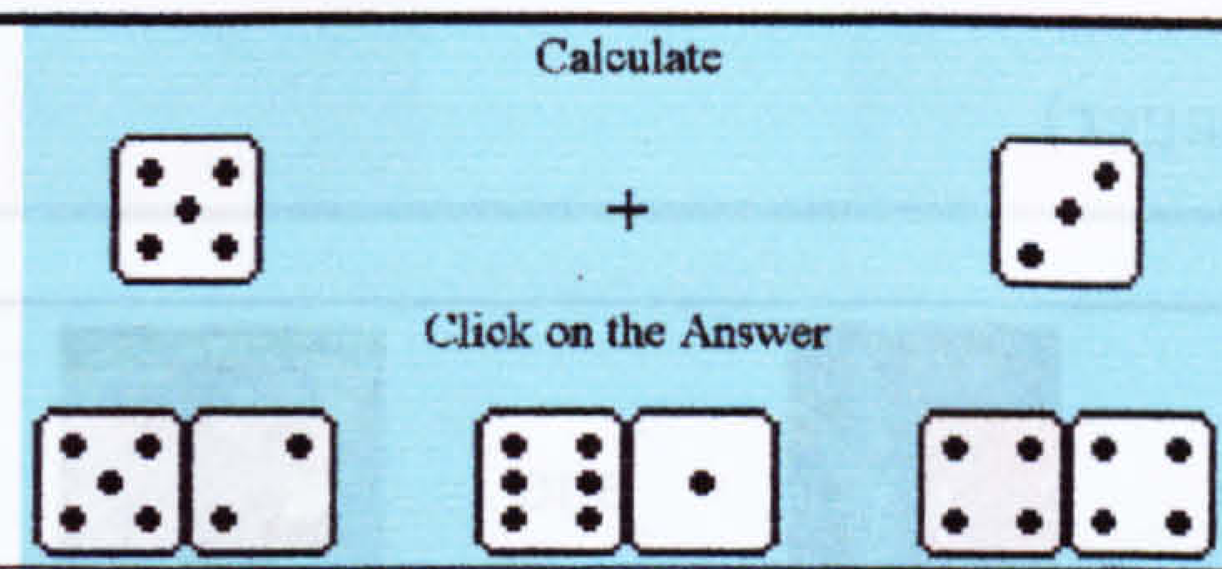
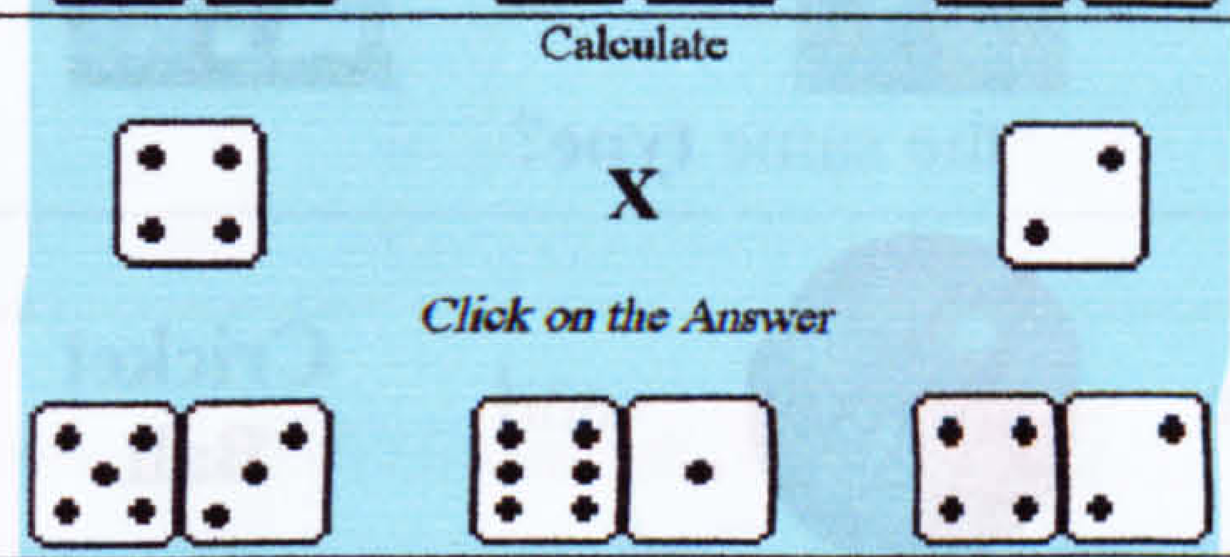
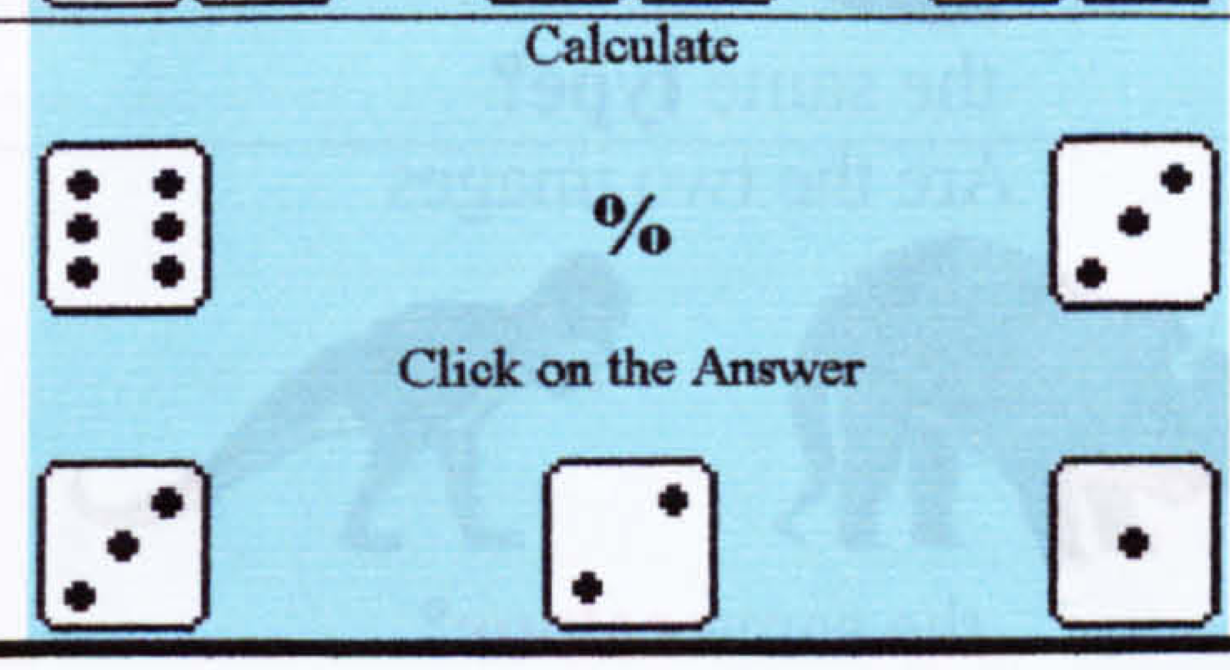
Information 2:

Study the map and click on Next



No.	Question	Answer
29		1
30		3
31		2
32		1
33		2

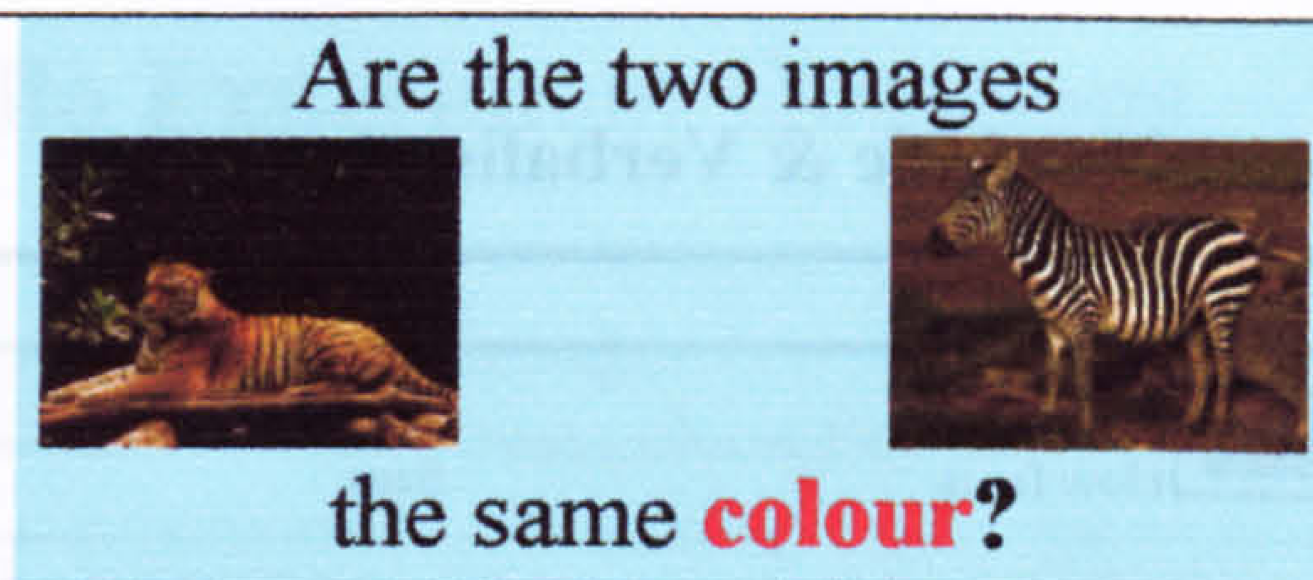
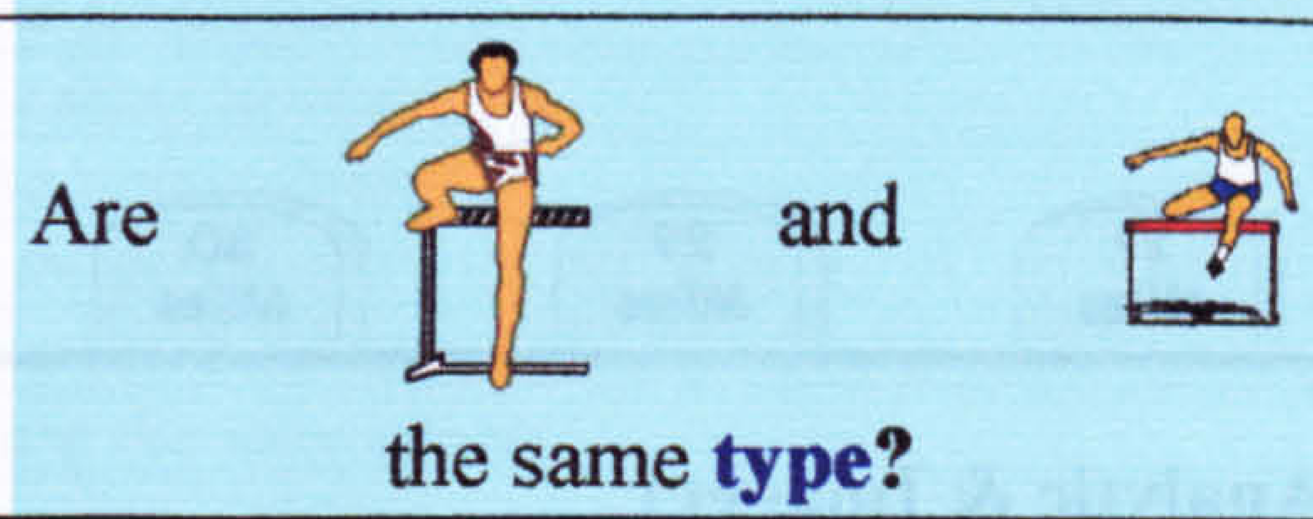
Mathematics (Analytic & Verbaliser)

No.	Question	Answer
26		3
27		1
28		1

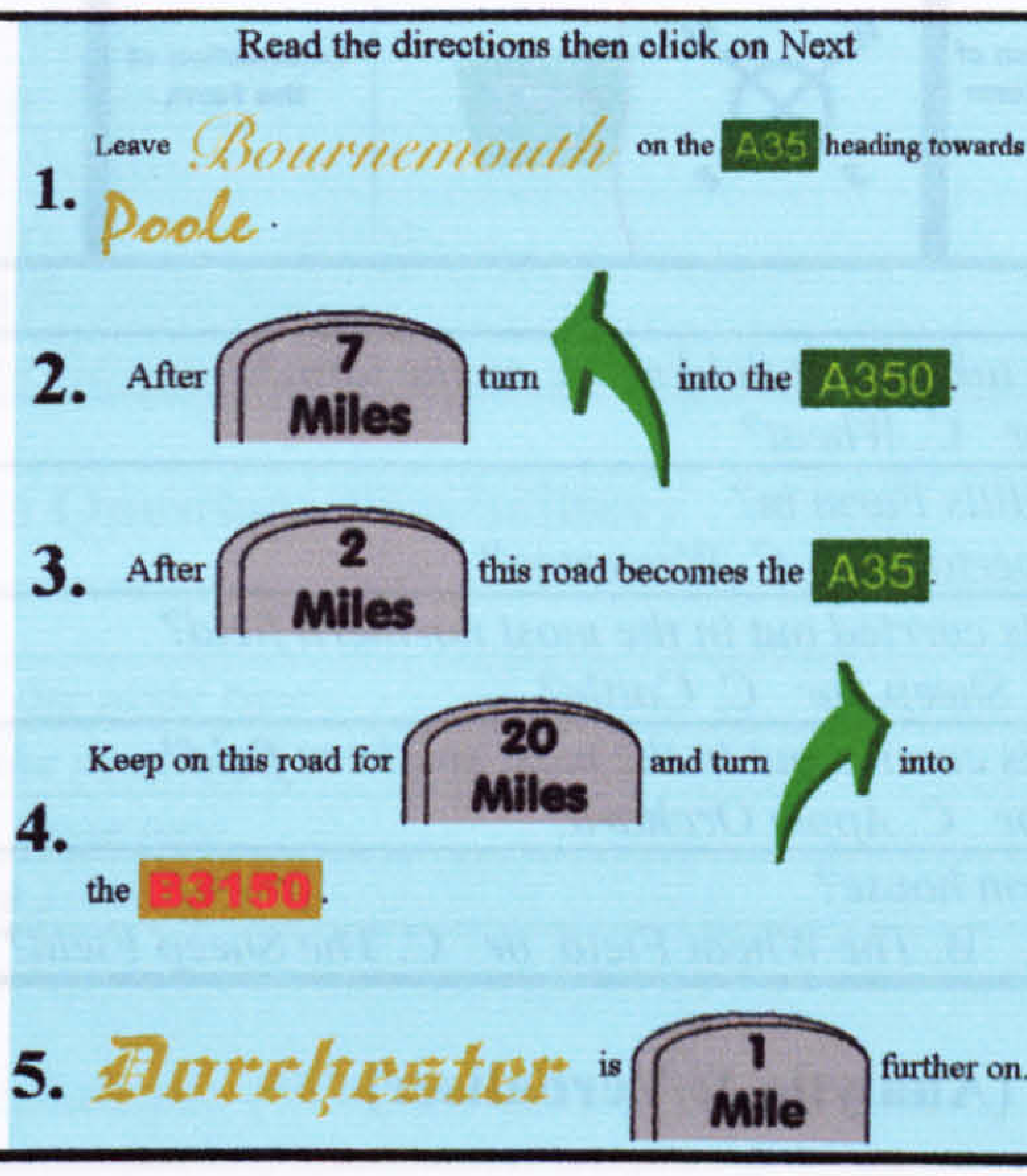
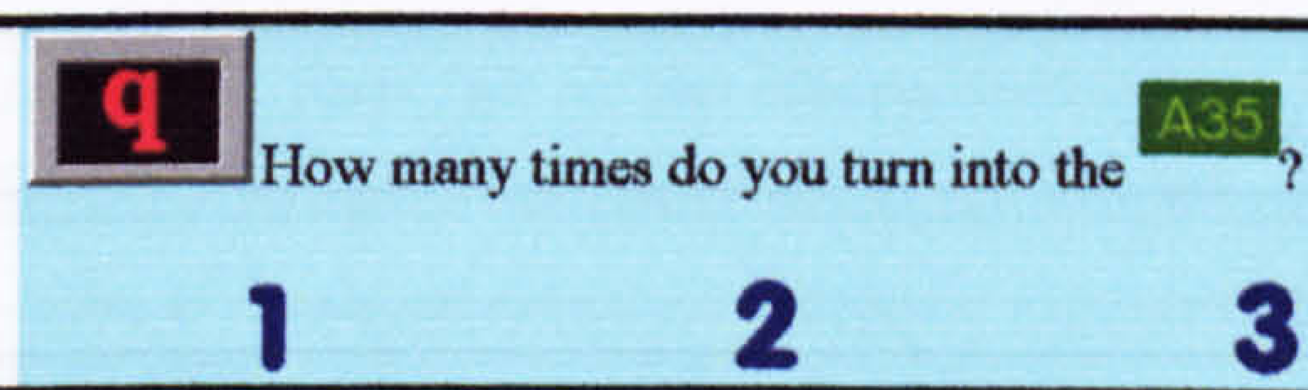
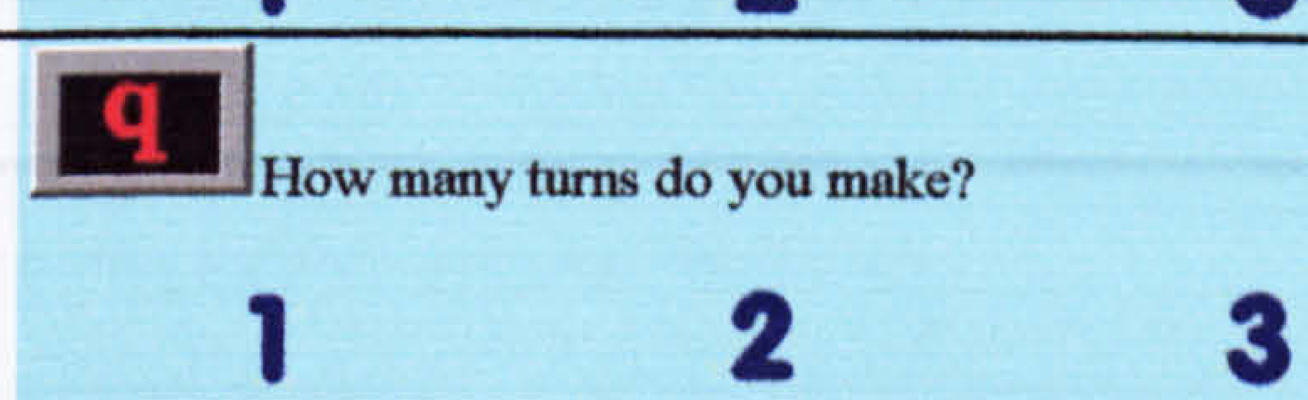
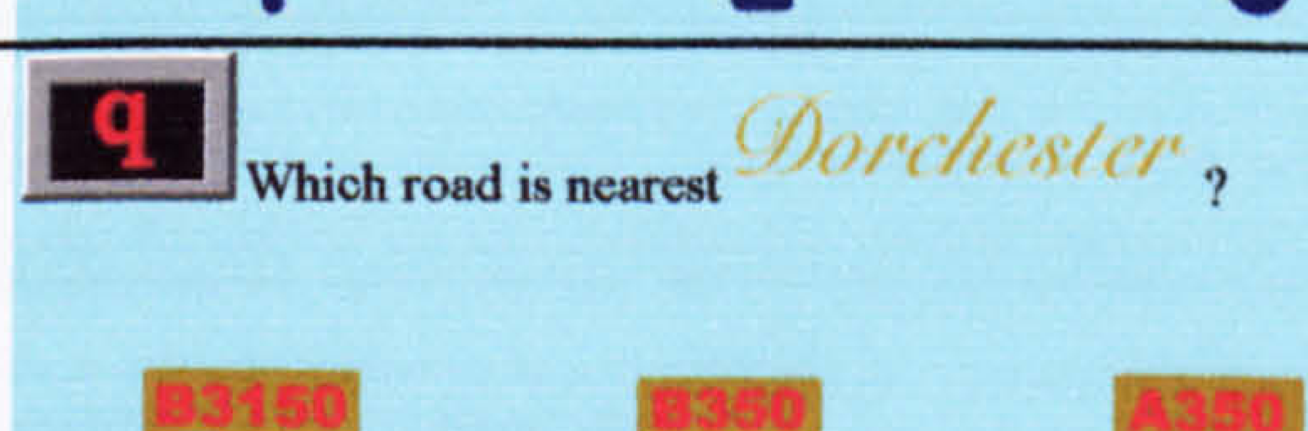
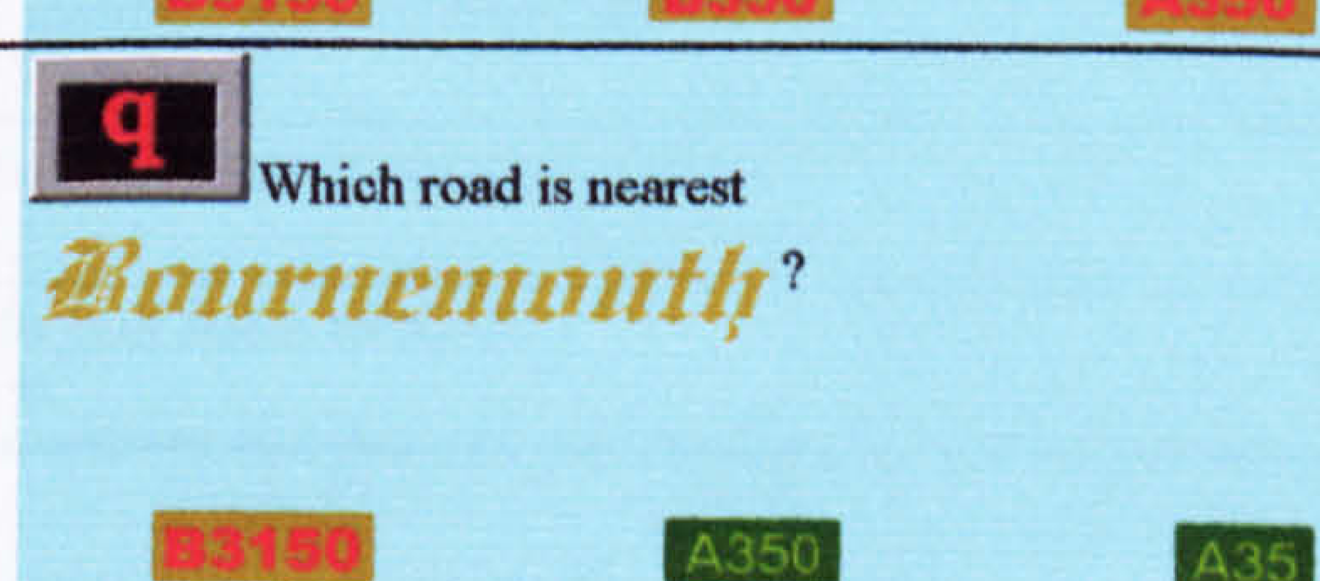
Appendix 6: Text/Image Experiment Questions

Comparison of objects (Imager)

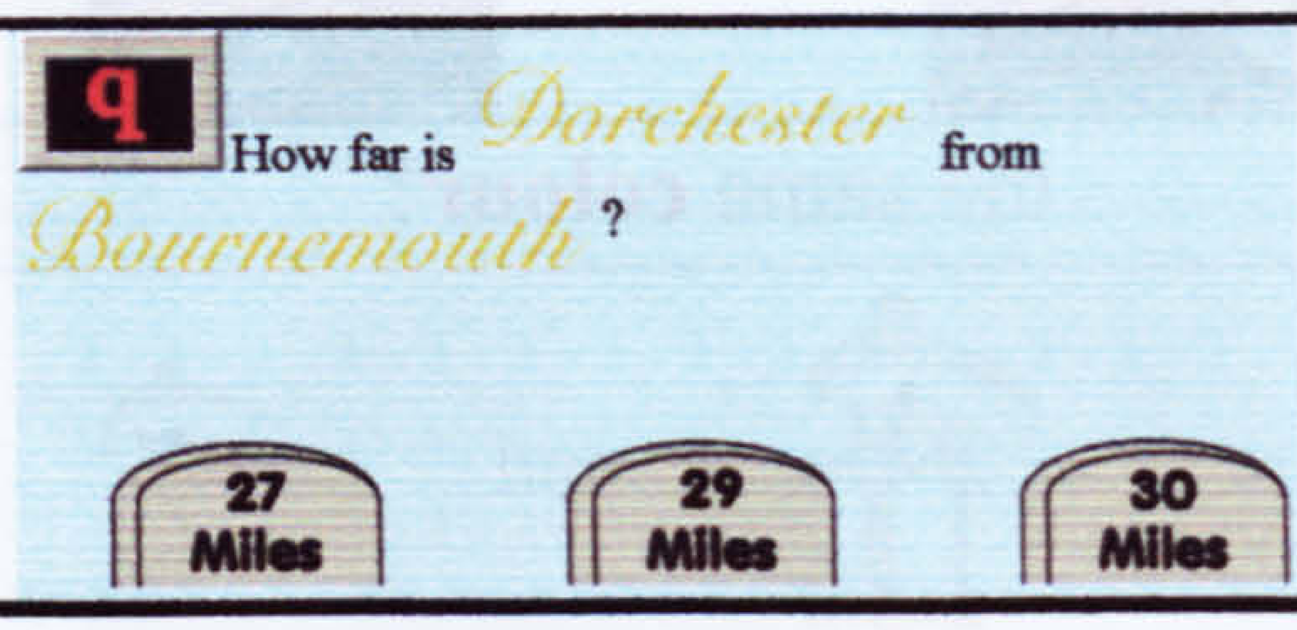
No.	Question	Answer
1	Are  and  the same **type**?	Yes
2	Are  and **Cricket Ball** the same **type**?	Yes
3	Are the two images   the same **colour**?	Yes
4	Are  and  the same **type**?	No
5	Are the two images   the same **colour**?	Yes
6	Are  and **Fish** the same **type**?	No
7	Are the two dinosaurs   the same **colour**?	No
8	Are  and  the same **type**?	No

9		No
10		Yes

Procedural without calculations (Wholist & Verbaliser)

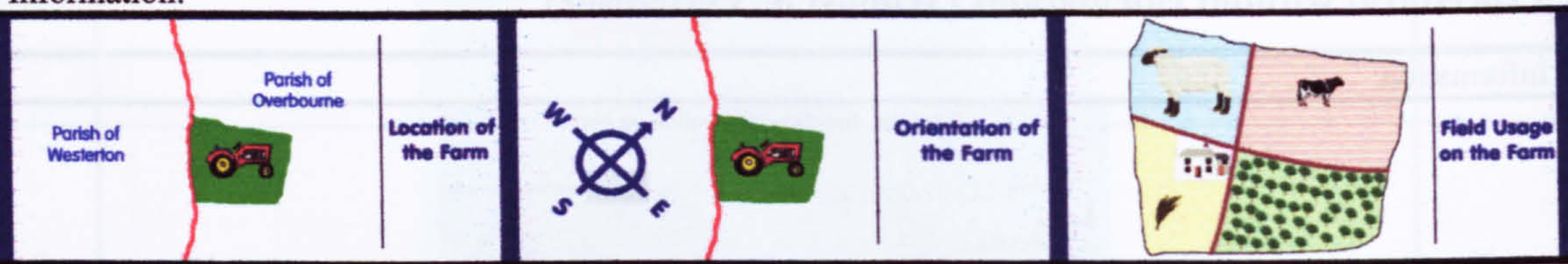
No.	Question	Answer
Information:		
12		1
13		2
14		1
15		3

Procedural with calculations (Analytic & Verbaliser)

No.	Question	Answer
11		3

Configuration question (Analytic & Imager)

Information:



No.	Question	Answer
16	*Which farming activity takes most field space on the farm?* A. *Sheep,* B. *Cattle, or* C. *Wheat?*	B
17	*Which parish is Four Hills Farm in?* A. *Overbourne,* B. *Overton, or* C. *Westerton?*	A
18	*What farming activity is carried out in the most northern field?* A. *Apple Orchard,* B. *Sheep,* *or* C. *Cattle?*	B
19	*What farming activity is carried out in the most southern field?* A. *Wheat,* B. *Sheep, or* C. *Apple Orchard?*	A
20	*In which field is the farm house?* A. *The Apple Orchard,* B. *The Wheat Field, or* C. *The Sheep Field?*	B

Mathematical questions (Analytic & Verbaliser)

No.	Question	Answer
21	*Calculate 13 + 25* A. *33,* B. *37, or* C. *38?*	C
22	*Calculate 6 x 12* A. *72,* B. *70, or* C. *68?*	A
23	*Calculate 28 % 4* A. *6,* B. *7, or* C. *8?*	B

Appendix 7: Audio Experiment Questions

Comparison of Objects Questions (Imagers)

No.	Question	Answer
2	*Lion and Tiger are the same type*	True
3	*Coal and Soot are the same colour*	True
4	*Sugar and Salt are the same colour*	True
5	*Finger and Ring are the same type*	False
6	*Grass and Leaf are the same colour*	True
7	*Tomato and Lettuce are the same colour*	False
8	*Log and Plank are the same type*	True
11	*Fish and Chips are the same colour*	True
12	*Beach and Desert are the same colour*	True
13	*Mug and Cup are the same type*	True
14	*Ash and Fire are the same colour*	False
15	*Glass and Water are the same type*	False
16	*Teeth and Tongue are the same colour*	False
17	*Daffodil and Canary are the same colour*	True
18	*Soldier and Sailor are the same type*	True
20	*Orange and Lemon are the same colour*	False

Comparison of Concepts Questions (Verbaliser)

No.	Question	Answer
1	*Rugby and Tennis are the same type*	True
9	*Light and Switch are the same type*	False
10	*Golf and Club are the same type*	False
19	*Ice and Skating are the same type*	False

Procedural without calculations (Wholist & Verbaliser)

Information 1:

Leave the bus station and turn left. Turn left at the library and keep going straight on. Pass the zebra crossing and turn right at the supermarket. The train station is on the left.

No.	Question	Answer
58	*The train station is in the same road as the supermarket.*	True
59	*The zebra crossing lies between the supermarket and the train station.*	False
60	*You turn left after leaving the bus station.*	False
61	*You reach the supermarket before reaching the library.*	False
62	*When you return you will reach the zebra crossing before the library.*	True

Information 2:

Walk sixty yards to the traffic lights then turn left. Keep going for sixty yards and turn left after the Kings Arms pub. The Post Office is one hundred yards further on, on the right hand side of the road.

No.	Question	Answer
54	*How many left-hand corners do you have to turn?* A. *3,* B. *2, or* C. *1?*	B
55	*How many right-hand corners do you have to turn?* A. *3,* B. *2, or* C. *1?*	A
57	*How many corners do you have to turn?* A. *3,* B. *2, or* C. *1?*	B

Procedural with calculations (Analytic & Verbaliser)

No.	Question	Answer
53	*How far is the Post Office?* A. *200 yards,* B. *210 yards, or* C. *220 yards?*	C
56	*How far is the Kings Arms?* A. *120 yards,* B. *100 yards, or* C. *90 yards?*	C

Mathematics Questions (Analytic & Verbaliser)

No.	Question	Answer
50	*Add seven and nine*	16
51	*Multiply three and seven*	21
52	*Divide eighteen by two*	9

Identification of 1 musical instrument (Imager)

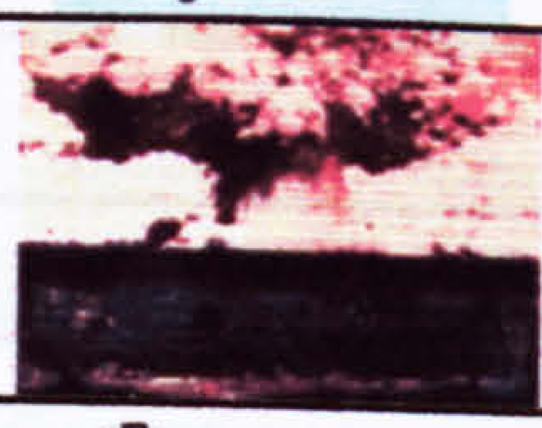
Information 1:		
Play Sound clips: Grand Piano, Electric Piano & Upright Piano		
No.	Question	Answer
21	*Identify the Instrument*	Grand Piano
22	*Identify the Instrument*	Electric Piano
Information 2:		
Play Sound clips: Harpsichord, Banjo & Sitar		
No.	Question	Answer
23	*Identify the Instrument*	Sitar
24	*Identify the Instrument*	Banjo
Information 3:		
Play Sound clips: Glockenspiel, Xylophone & Tubular Bells		
No.	Question	Answer
25	*Identify the Instrument*	Xylophone
26	*Identify the Instrument*	Glockenspiel
Information 4:		
Play Sound clips: Hammond Organ, Church Organ & Reed Organ		
No.	Question	Answer
27	*Identify the Instrument*	Reed Organ
28	*Identify the Instrument*	Hammond Organ
Information 5:		
Play Sound clips: Accordion, Harmonica & Clarinet		
No.	Question	Answer
29	*Identify the Instrument*	Harmonica
30	*Identify the Instrument*	Clarinet
Information 6:		
Play Sound clips: Acoustic Guitar, Electric Guitar & Harp		
No.	Question	Answer
29	*Identify the Instrument*	Harp
30	*Identify the Instrument*	Acoustic Guitar
Information 7:		
Play Sound clips: Trumpet, Trombone & French Horn		
No.	Question	Answer
29	*Identify the Instrument*	Trumpet
30	*Identify the Instrument*	French Horn

Identification of 2 musical instruments (Imager)

Information 1:		
Play Sound clips: Grand Piano, Electric Piano & Upright Piano		
No.	Question	Answer
35	*Identify the Instruments* A. *Grand Piano and Electric Piano,* B. *Acoustic Guitar and Grand Piano, or* *C. Electric Piano and Harp?*	B
36	*Identify the Instruments* A. *Harmonica and Clarinet,* B. *Accordion and Clarinet, or* *C. Harmonica and Accordion?*	B
37	*Identify the Instruments* A. *Harpsichord and Harpsichord,* B. *Banjo and Sitar, or* *C. Harpsichord and Banjo?*	C
38	*Identify the Instruments* A. *Trombone and Trumpet,* B. *French Horn and Trombone, or* *C. Trumpet and French Horn ?*	C
39	*Identify the Instruments* A. Electric Piano and Electric Piano, B. Grand Piano and Electric Piano, or *C.* Grand Piano and Grand Piano?	A

Identification of sound effects (Imager)

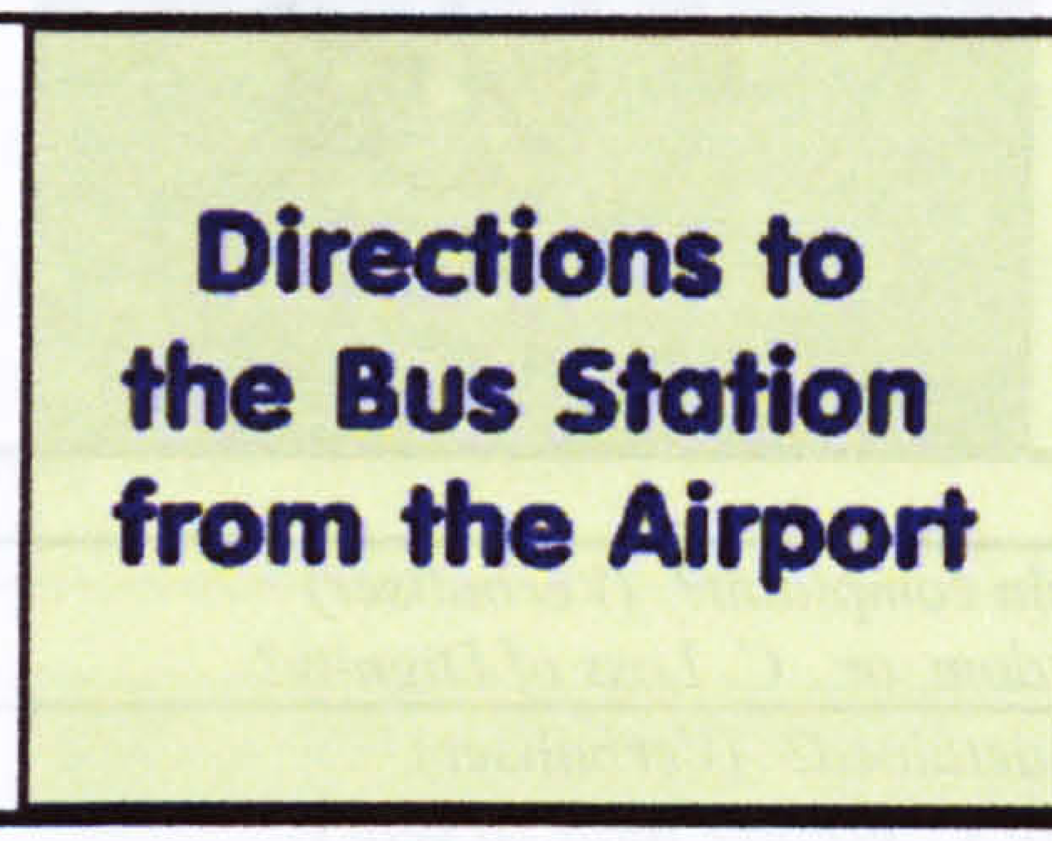
Identify the sound effect, by matching the sound with an image				
No.	Question			Answer
40				B
41				B
42				A
43				C
44				B
45				B

46				C
47				B
48				C
49				A

Appendix 8: Video Experiment Questions

Procedural questions (Wholist & Verbaliser)

Video 1:



No.	Question	Answer
6	*How are you travelling?* A. *By bus,* B. *by foot, or* C. *by taxi?*	B
7	*How many times do you turn right?* A. *0,* B. *1, or* C. *2?*	C
8	*Which building is reached first?* A. *Library,* B. *Office Block, or* C. *Town Hall?*	C
9	*The last road is opposite which building?* A. *Library,* B. *Office Block, or* C. *Town Hall?*	B
10	*What is the Final Destination?* A. *Bus Station,* B. *Library, or* C. *Town Hall?*	A

Detailed comprehension questions (Analytic, Imager & Verbaliser)

Video 1:

No.	Question	Answer
13	*Who designed the Palace? (Verbaliser)* A. *John Vanbrugh,* B. *Capability Brown, or* C. *King George?*	A
14	*How long had the designer been an architect? (Verbaliser)* A. *6,* B. *10, or* C. *15 years?*	A
15	*How many people were walking up the stairs? (Imager)* A. *1,* B. *2 or* C. *3?*	B
16	*The camera zooms in on which feature? (Imager)* A. *The Grand Bridge,* B. *The Palace,* C. *The Lake and gardens?*	B
17	*How was the building described? (Verbaliser)* A. *Georgian,* B. *Barogue or* C. *Classical?*	C

Video 2:

No.	Question	Answer
20	*What was the prisoner's main complaint? (Verbaliser)* A. *Hunger,* B. *Loss of freedom, or* C. *Loss of Dignity?*	C
21	*How long was the prisoner detained? (Verbaliser)* A. *Less than,* B. *equal to, or* C. *greater than 20 years?*	A
22	*How many escape attempts were mentioned? (Verbaliser)* A. *2,* B. *,3 or* C. *4?*	C
23	*What sound alerts the pursuers? (Imager)* A. *Cobble Stones,* B. *Roof Tiles, or* C. *Gun Shot?*	B
24	*How many people speak? (Imager)* A. *1,* B. *2, or* C. *3?*	C

Video 3:

No.	Question	Answer
27	*How long was the video? (Imager)* A. *Less than,* B. *equal to, or* C. *greater than 10 seconds?*	C
28	*How many captions were seen? (Imager)* A. *2,* B. *3, or* C. *4?*	C
29	*How many faces were seen? (Imager)* A. *4,* B. *5, or* C. *6?*	C
30	*How many faces are black and white? (Imager)* A. *2,* B. *3, or* C. *4?*	A
31	*How many instruments are heard? (Imager)* A. *2,* B. *3, or* C. *4?*	A

Video 4:

No.	Question	Answer
34	*What is the subject of the video? (Imager)* A. *Rock Band Promo Video,* B. *Musical Equipment Advertisement, or* C. *Games Show Prize?*	C
35	*How many separate items were mentioned? (Verbaliser)* A. *4,* B. *6, or* C. *8?*	C
36	*Did the caption match the narration? (Verbaliser)* A. *Yes – Exactly,* B. *Yes - In meaning, or* C. *No – Misleading?*	A
37	*What is the sequencer used for? (Verbaliser)* A. *Perfect sound,* B. *Keyboards, or* C. *Lights?*	C
38	*How many watts is the mixing desk? "(Verbaliser)* A. *600w,* B. *800w. or* C. *1,000w?*	C

Video 5:

No.	Question	Answer
41	*What is the first reason that a drink is required? (Verbaliser)* A. *'For special courage',* B. *'To steady my nerves', or* C. *'To wet my whistle'?*	B
42	*How many people were seen? (Imager)* A. *A crowded room,* B. *3, or* C. *4?*	C
43	*What was the waiter carrying? (Imager)* A. *A tray,* B. *a bottle, or* C. *a cloth?*	A
44	*What was the Nitro-glycerine to be used for? (Verbaliser)* A. *To blow up a train,* B. *to blow up a plane, or* C. *to blow up a building?*	A
45	*How was the bottle handled? (Imager)* A. *Carefully put down,* B. *Quickly emptied, or* C. *slammed on the counter?*	C

General comprehension questions (Wholist)

For each of the above videos:

No.	Question
1	*What is the purpose of the video?* A. *Humour, or* B. *Drama or Information?*
2	*What is the atmosphere of the video?* A. *Tense,* B. *Neutral, or* C. *Relaxed?*

Mathematical questions (Analytic & Verbaliser)

No.	Question	Answer
1	*Calculate 17 + 28* *= Between 30 – 49?*	45
2	*Calculate 6 x 7* *= Between 30 – 49?*	42
3	*Calculate 32 x 8* *= Between 1 – 10?*	4

PAGE NUMBERING AS ORIGINAL

Glossary

ANOVA: Analysis of variance calculations used to test the hypothesis that means from two or more samples are equal.

Cognitive style: the consistent underlying method of an individual's thinking and perceiving that affects the way in they perceive and respond to events and ideas.

Degrees of Freedom: a value associated with the number of data points in a sample that is used in determining the significance level. The number of degrees of freedom varies depending on the type of calculation being performed.

Eta Squared: the Magnitude of Effect that assesses the degree to which variability in the performance of subject can be attributed to their CS classification. The values range from 0.00 that indicates no link, to 1.00 that indicates a strong link.

The **observed power**. The probability of a type II error occurring (incorrectly rejecting the null hypothesis). The values range from 0.00 which indicates that there is a greater probability of a type II error occurring to 1.00 which indicates that there is a greater probability that the conclusion based on the significance figure is correct.

One-way ANOVA: One-way Analysis of variance. Used to test the hypothesis that means from two samples are equal. Significance levels of less than 0.05 indicate that the two samples are significantly different. Significance values of between 0.05 and 0.10 indicate that the two samples are marginally different. Where no significant or marginal effect is detected the hypothesis is accepted.

Significance: an indicator that determines whether hypothesis should be accepted or rejected e.g. in ANOVA or t-test calculations that test the hypothesis that means from two or more samples are equal.

- A significance value of less than 0.05 ($p > 0.05$) indicates that the hypothesis is correct.
- A significance value of between 0.05 and 0.10 indicates that there is marginal evidence that the hypothesis is correct.
- A significance value of over 0.10 indicates that there is no evidence that the hypothesis is correct.

T-test: Used to test the difference between the means of two samples. Significance levels of less than 0.05 indicate that the two samples are significantly different. Significance values of between 0.05 and 0.10 indicate that the two samples are marginally different.

Telecare: the use of telecommunication technology (including phone lines, video phones, Internet access) for the delivery of primary care to the elderly, house-bound, disabled or otherwise disadvantaged, in their own homes.

Tukey: A multiple comparison test that evaluates the level of significance in the difference between two pairs of means.

Two-way ANOVA: Two-way Analysis of variance. Used to test the hypothesis that means from more than two samples are equal. Significance levels of less than 0.05 indicate that the two samples are significantly different. Significance values of between 0.05 and 0.10 indicate that the two samples are marginally different. Where no significant or marginal effect is detected the hypothesis is accepted.

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List of Publications resulting from this thesis

1. John, D., Jerrams-Smith, J., Boucouvalas, A. C. and Heathcote, D., 1998. Telecare Companion: An Adaptive Telecare System. *Proceedings of the First International Symposium on Communication Systems & Digital Signal Processing, CSDSP'98*, Sheffield, UK. Sheffield Hallam University Press, pp 603-606

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